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The probability of failure when the characteristic values are used as a design method

La probabilité de ruine quand la méthode des valeurs caractéristiques est utilisée

Die Versagenswahrscheinlichkeit, wenn die charakteristischen Werte als Bemessungsmethode verwendet werden

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The only method to determine the dimensions of structures which seems to have a logical justification, would be a form of calculation giving an equal reliability (or equal probability of failure) in different parts of the structure.

Another, and purely practical, requirement for this calculation method is simplicity, as the method should be available for the average engineer in his everyday work.

It seems possible to determine by computers the probability of failure for different types of structures. The question is, can we find a general and relatively simple method of calculation, which gives automatically a given and similar reliability to the different parts of the structure under consideration? If this is not possible, what method would best fulfil the previous conditions?

Four different design methods will be studied in the following, and for simplicity called methods 1,2,3 and 4.

A simple and rather general model of the reliability can be presented as follows:

The condition for failure will be given by

(1) $g(x_1 \ldots x_n) \leqq 1$

where $x_1 \ldots x_n$ represent the various quantities of the structural element or the external forces and moments loading this element.

We assume that the distribution functions of $x_1 \ldots x_n$ are known, and denote the mean-values of these quantities by $m_1 \ldots m_n$

and the standard deviations by $\sigma_1 \ldots \sigma_n$.

For the probability of failure we have

(2) $P(g(x_1 \ldots x_n) \leqq 1)$

The four different design methods which will be compared are as follows:

Method 1. We choose the mean values of the r first quantities $x_1 \ldots x_r$ (the internal properties of the structural element) and the n-r quantities $x_{r+1} \ldots x_n$ (the external forces and moments) so that

$$g(m_1 \ldots m_r,\ k \cdot m_{r+1} \ldots k \cdot m_n) = 1$$

We always use the same "total safety factor" k and try to determine k so that in some common cases

$$P(g(x_1 \ldots x_n) \leqq 1) = c$$

where we denote the probability of failure considered as suitable by c.

Method 2. We choose the mean values of the various quantities so that

$$g(m_1 \ldots m_r, k \cdot m_{r+1} \ldots k \cdot m_n) = 1$$

and use, depending on the values of $\rho_1 = \sigma_1/m_1 \ldots \rho_n = \sigma_n/m_n$ and different functions g, various "total safety factors" k, so that in all cases

$$P(g(x_1 \ldots x_n) \leqq 1) = c$$

Method 3. We choose the various mean values so that

$$g(m_1 \pm \alpha \cdot \sigma_1 \ldots m_n \pm \alpha \cdot \sigma_n) = 1 \text{ (+ or - chosen unfavourably)}$$

We always use the same "characteristic coefficient" α and try to determine α so that in some common cases

$$P(g(x_1 \ldots x_n) \leqq 1) = c$$

Method 4. We choose the mean values so that

$$g(m_1 \pm \alpha \cdot \sigma_1 \ldots m_n \pm \alpha \cdot \sigma_n) = 1 \text{ (+ or - chosen unfavourably)}$$

and use various "characteristic coefficients" α depending on the values of $\rho_1 \ldots \rho_n$ and g, so that in all cases

$P(g(x_1 \ldots x_n) \leqq 1) = c$

We see immediately that methods 2 and 4 strive for mathematical exactness and methods 1 and 3 aim at simplicity in everyday use.

We shall now study and compare these methods in four different cases.

1. The simplest model of reliability is the case when both the capacity of the structure x_1, and the external load x_2, are normal and independent with mean values m_1, m_2 and s.d. σ_1, σ_2.

The probability of failure is then

$$(3) \qquad P(x_1/x_2 \leqq 1) = P((x_1 - x_2) \leqq 0$$

As we know, the distribution of $(x_1 - x_2)$ is also normal with

$$(4) \qquad \begin{cases} m = m_1 - m_2 \\ \sigma = \sqrt{\sigma_1^2 + \sigma_2^2} \end{cases}$$

and we have

$$(5) \qquad P(x_1/x_2 \leqq 1) = \Phi\left(\frac{m_2 - m_1}{\sqrt{\sigma_1^2 + \sigma_2^2}}\right)$$

where

$$(6) \qquad \Phi(\beta) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\beta} e^{-t^2/2} \cdot dt$$

now writing

$$\begin{cases} \sigma_1 = \varrho_1 \cdot m_1 \\ \sigma_2 = \varrho_2 \cdot m_2 \end{cases}$$

and $m_1/m_2 = k$

we get

$$(7) \qquad P((x_1/x_2) \leqq 1) = \Phi\left(\frac{1 - k}{\sqrt{\varrho_1^2 \cdot k^2 + \varrho_2^2}}\right)$$

which gives the probability of failure when different "total safety factors" are used.

In the same way we get

$$(8) \qquad k = \frac{1 + \sqrt{1 - (1 - \varrho_1^2 \cdot \beta^2) \cdot (1 - \varrho_2^2 \cdot \beta^2)}}{1 - \varrho_1^2 \cdot \beta^2}$$

to calculate "the total safety factors" corresponding to certain $\Phi(\beta) = c$

Using the "characteristic values" we write

$$(9)\quad \begin{cases} x_1^* = m_1 - \alpha \cdot \sigma_1 \\ x_2^* = m_2 + \alpha \cdot \sigma_2 \end{cases}$$

Through $x_1^* = x_2^*$ we get for k'

$$(10)\quad k' = m_1/m_2 = \frac{1 + \alpha \cdot \rho_2}{1 - \alpha \cdot \rho_1}$$

and β

$$(11)\quad \beta = \frac{-\alpha(\sigma_1 + \sigma_2)}{\sqrt{\sigma_1^2 + \sigma_2^2}} = \frac{-\alpha(\rho_1 + \rho_2)}{\sqrt{\rho_1^2 + \rho_2^2 + 2\cdot\alpha^2\cdot\rho_1^2\rho_2^2 + 2\alpha\rho_1\rho_2(\rho_1 - \rho_2)}}$$

to define the dependence between α, β and k'. By k' we denote "the total safety factor", which gives as result the same β as we get using the corresponding α from (10).

These relations are illustrated in Fig.1 and Fig.2. The equalities (7), (8), (10) and (11) have been solved for some special cases of ρ_1 and ρ_2, which are usual in practice and the results are given in Table 1.

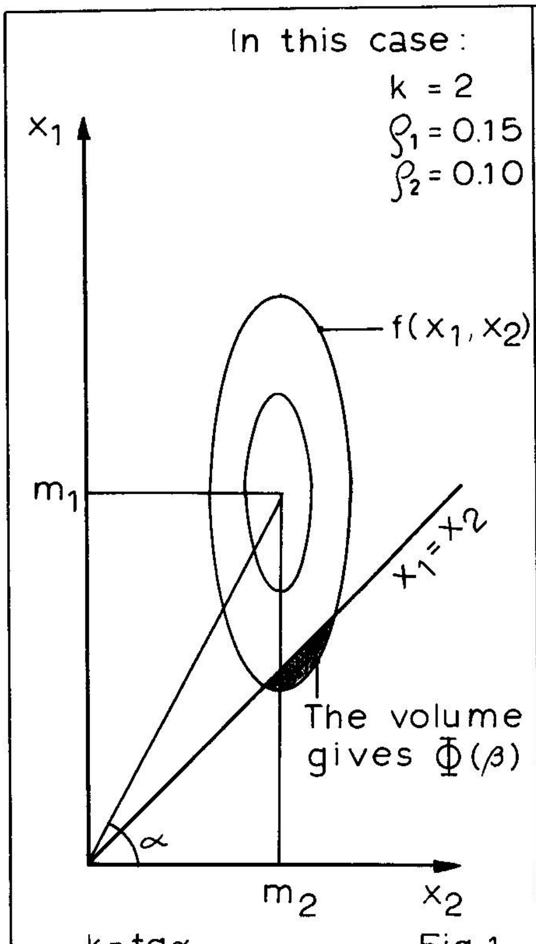

Fig 1

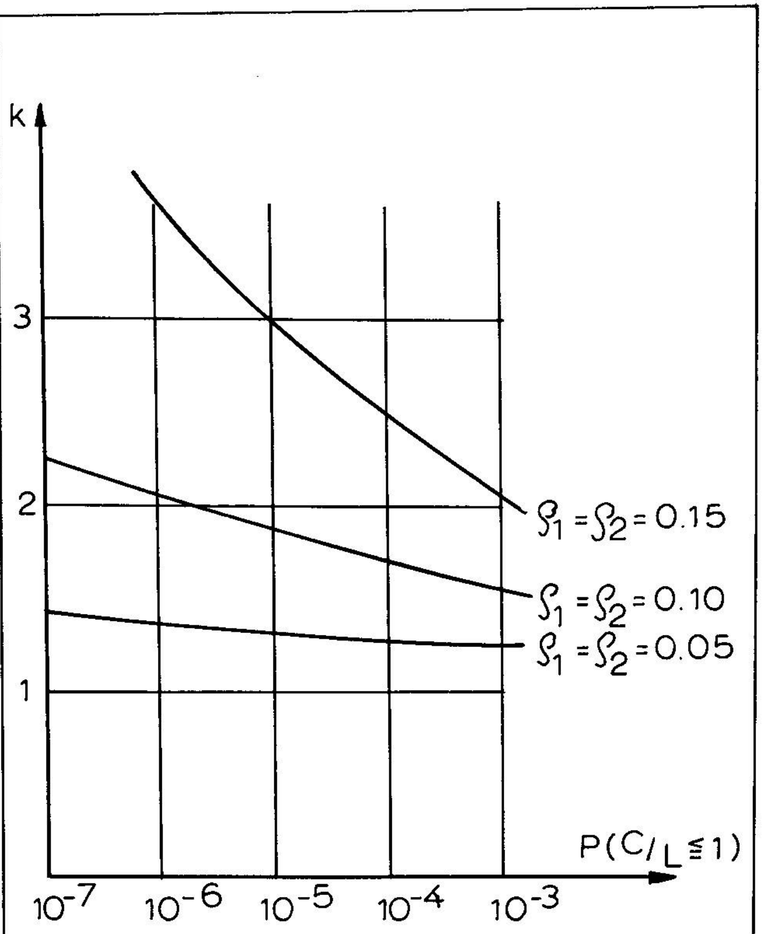

Fig 2

Table 1

	σ/m		k = 2		$-\beta$ = 4,65	α = 3,30				α = 4,25	
	x_1	x_2	$-\beta$	$\Phi(\beta)$	k	$-\beta$	Φ/β	k'	k/k'	k'	k/k'
1	0,05/1	0,05/1	8,95	$\sim 10^{-17}$	1,40	4,60		1,40	1,00		
2	0,10/1	0,05/1	4,85		1,92	4,09		1,74	1,10		
3	0,15/1	0,05/1	3,29		3,35	3,75	$\sim 10^{-5}$	2,31	1,45	3,35	1,00
4	0,05/1	0,10/1	7,07		1,59	4,65	$\sim 10^{-6}$	1,59	1,00		
5	0,10/1	0,10/1	4,47		2,07	4,43		1,99	1,04		
6	0,15/1	0,10/1	3,16		3,46	4,01		2,64	1,31		
7	0,05/1	0,15/1	5,55		1,81	4,53		1,79	1,01		
8	0,10/1	0,15/1	4,00		2,26	4,58		2,23	1,01		
9	0,15/1	0,15/1	2,98	$\sim 10^{-3}$	3,62	4,17		2,96	1,22		

The complete analysis of these results will be given later, but we can now note that

<u>Method 1</u> with k=2 gives $-8,95 \leqq \beta \leqq -2,98$, which shows that the method is mathematically not justified. ($10^{-17} < \Phi(\beta) < 0,14 \cdot 10^{-2}$)

<u>Method 2</u> with $c \approx 10^{-6}$; $\beta = 4,65$ gives $1,40 \leqq k \leqq 3,62$. The method is mathematically justified but the definition of k is too complicated

<u>Method 3</u> with $\alpha = 3,3$ gives $-4,65 \leqq \beta \leqq -3,75$, which shows that the method is mathematically more correct than 1, but a little more complicated. ($0,16\ 10^{-5} < \Phi(\beta) < 0,9 \cdot 10^{-4}$)

<u>Method 4</u> with $c \approx 10^{-6}$; $\beta = 4,65$ gives $3,3 \leqq \alpha \leqq 4,25$. The method is mathematically justified but the definition of α is too complicated.

2. A more developed model for determining the reliability is when both the capacity of the structural element and the external load are linear functions

$$(12)\quad \begin{cases} \sum_{i=1}^{m} a_i \cdot x_i & \text{(capacity = C)} \\ \sum_{i=m+1}^{n} a_i \cdot x_i & \text{(load = L)} \end{cases}$$

Assuming that x_i are all independent and normal with m_i and σ_i we then have the mean and s.d. of C − L

$$(13)\quad m = \sum_{i=1}^{m} a_i \cdot m_i - \sum_{i=m+1}^{n} a_i \cdot m_i$$

(13) $$\sigma = \sqrt{\sum_{i=1}^{n} (a_i \cdot \sigma_i)^2}$$

As the probability of failure we obtain

(14) $$P(C/L \leqq 1) = \Phi\left(\frac{\sum_{i=m+1}^{n} a_i \cdot m_i - \sum_{i=1}^{m} a_i \cdot m_i}{\sqrt{\sum_{i=1}^{n} (a_i \cdot \sigma_i)^2}}\right)$$

We assume now that values ρ_i are independent of m_i, and write

(15) $$\begin{cases} \sum_{i=m+1}^{n} a_i \cdot m_i = \sum_{i=1}^{m} a_i \cdot m_i' \\ \sigma_i' = \rho_i \cdot m_i' \end{cases}$$

We then have

(16) $$P(C/L \leqq 1) = \Phi\left(\frac{(1-k) \sum_{i=m+1}^{n} a_i \cdot m_i}{\sqrt{k^2 \cdot \sum_{i=1}^{m} (a_i \cdot \sigma_i')^2 + \sum_{i=m+1}^{n} (a_i \cdot \sigma_i)^2}}\right)$$

and

(17) $$k = \frac{1 + \sqrt{1 - (1 - C_1 \cdot \beta^2)(1 - C_2 \cdot \beta^2)}}{1 - C_1 \cdot \beta^2}$$

where

(18) $$C_1 = \frac{\sum_{i=1}^{m} (a_i \cdot \sigma_i')^2}{\left(\sum_{i=m+1}^{n} a_i \cdot m_i\right)^2} \quad ; \quad C_2 = \frac{\sum_{i=m+1}^{n} (a_i \cdot \sigma_i)^2}{\left(\sum_{i=m+1}^{n} a_i \cdot m_i\right)^2}$$

We can see that equations (16) and (17) correspond to the earlier equations (7) and (8) for that special case of (12) which was treated before.

Using now the "characteristic values" we get

(19) $$k' = \frac{\sum_{i=m+1}^{n} a_i (m_i + \alpha \cdot \sigma_i)}{\sum_{i=1}^{m} a_i (m_i' - \alpha \cdot \sigma_i')}$$

and we can calculate the corresponding β-values from (16). Some cases with $n=3$ and $m=1$ have been treated, and the results are given in Table 2. The values for m_1', σ_1', m_2, σ_2, m_3, σ_3 have been chosen so that x_1 could represent the capacity of an element, while x_2 and x_3 could represent dead and live load in a practical case. The analysis of this case follows later.

Table 2

	σ/m			k=2	$-\beta = 4{,}65$	α = 2,80		α = 3,60	
	x_1	x_2	x_3	$-\beta$	k	k'	k/k'	k'	k/k'
1	0,1 /1,0	0,02/0,4	0,06/0,6	4,77	1,95	1,70	1,15		
2	0,1 /1,0	0,02/0,4	0,09/0,6	4,38	2,04	1,82	1,12		
3	0,1 /1,0	0,02/0,4	0,12/0,6	4,27	2,15	1,93	1,12		
4	0,1 /1,0	0,04/0,8	0,02/0,2	4,88	1,91	1,63	1,17	1,91	1,00
5	0,1 /1,0	0,04/0,8	0,03/0,2	4,85	1,92	1,66	1,16		
6	0,1 /1,0	0,04/0,8	0,04/0,2	4,81	1,94	1,70	1,14		
7	0,05/1,0	0,02/0,4	0,06/0,6	8,45	1,44	1,42	1,02		
8	0,05/1,0	0,02/0,4	0,09/0,6	7,35	1,56	1,52	1,03		
9	0,05/1,0	0,02/0,4	0,12/0,6	6,35	1,69	1,62	1,04		
10	0,05/1,0	0,04/0,8	0,02/0,2	9,15	1,38	1,36	1,02		
11	0,05/1,0	0,04/0,8	0,03/0,2	8,95	1,40	1,39	1,01		
12	0,05/1,0	0,04/0,8	0,04/0,2	8,58	1,42	1,42	1,00		

What has been said earlier of case 1 holds good here. In addition it can be seen that the α-values giving β =-4,65 are considerably smaller than in case 1. In case 1 we had $3{,}3 \leqq \alpha \leqq 4{,}25$ and here $2{,}8 \leqq \alpha \leqq 3{,}60$.

This will be explained. From (16) and (19) we obtain

$$(20) \quad \alpha = -\beta \frac{\sqrt{k'^2 \sum_{i=1}^{m} (a_i \cdot \sigma_i')^2 + \sum_{i=m+1}^{n} (a_i \cdot \sigma_i)^2}}{k' \sum_{i=1}^{m} a_i \cdot \sigma_i' + \sum_{i=m+1}^{n} a_i \cdot \sigma_i}$$

Replacing the variables we have

$$(21) \quad \alpha = -\beta \frac{\sqrt{\sum_{i=1}^{n} (u_i)^2}}{\sum_{i=1}^{n} u_i}$$

At least two conclusions can be made from (21):

- α decreases with increasing n and constant
- α decreases with u_i values of the same size and increases with u_i values of variable sizes.

It can also be seen from Fig. 1 and Table 2 that both these conclusions hold good.

Case 2 is the most general case which the author has been able to treat in an exact mathematical form. More complicated cases, such as cases 3 and 4, have been treated approximately by computer.

3. As the third example we shall study the breakage of a rectangular prestressed or reinforced concrete element, when the section is partly cracked and the tension of the reinforcement has reached the yield-limit. The section is loaded with a moment.

The condition of failure is, on the basis of elementary statics:

$$(22) \quad 1 - \frac{S_{1g} + S_{1p}}{x_1\left(x_2 - \frac{x_6 \cdot x_1}{x_4 \cdot x_5 \cdot x_3}\right)} \leqq 0$$

where S_{1_g} = the external moment caused by the invariable load.

S_{1_p} = the external moment caused by the extremal value of the variable load.

x_1 = the tensile-load of the reinforcement, when the tension has reached the yield-limit.

x_2 = the distance of the reinforcement from the compressed edge of the element.

x_3 = the fullness of the compressed section of the element, (usually called β)

x_4 = the ultimate compressive strength of the concrete.

x_5 = the breadth of the compressed zone.

x_6 = the distance of the centre of gravity of the compressed zone from the compressed edge in relation to the height of the compressed zone.

All distributions are assumed to be normal. The means and standard deviations are given in Table 3. The values of k corresponding to the probability of failure 10^{-6} have been calculated by computer and the values k′ have been found with (23) using $\alpha = 1,90$.

$$(23) \quad k' = \frac{S^*_{1_g} + S^*_{1_p}}{x_1^* \left(x_2^* - \frac{x_1^* \, x_3^*}{x_4^* \, x_5^* \, x_6^*}\right)} : \frac{m_{S_{1g}} + m_{S_{1p}}}{m_{x1}\left(m_{x2} - \frac{m_{x1} \, m_{x3}}{m_{x4} \, m_{x5} \, m_{x6}}\right)}$$

It can be seen that the greatest α-value among these cases (giving k/k′ = 1,0 in case 10) is 2,20.

The analysis of the results follows later.

4. As the last example we again study a similar reinforced concrete section, but the section is now loaded with a moment and a normal force. We get the condition of failure [9]

$$(24) \quad 1 - \frac{S_1 + S_2(x_2 - c)}{x_2(x_1 + S_2)\left(1 - \frac{x_6(x_1 + S_2)}{x_2 \, x_3 \, x_4 \, x_5}\right)} \leqq 0$$

The loads and forces are dependent in the following ways:

Cases 1 and 2: $\begin{cases} S_{1g} = 0{,}5\ g \\ S_{2g} = 1{,}0\ S_{1g} \end{cases}$ $\begin{cases} S_{1p} = 0{,}08\ p_2 + 0{,}12\ p_3 \\ S_{2p} = 0{,}10\ p_1 + 0{,}20\ p_2 \end{cases}$

Cases 3 and 4: $\begin{cases} S_{1g} = 0{,}2\ g \\ S_{2g} = 1{,}5\ S_{1g} \end{cases}$ $\begin{cases} S_{1p} = 0{,}20\ p_1 + 0{,}30\ p_2 \\ S_{2p} = 0{,}40\ p_1 + 0{,}10\ p_2 \end{cases}$

g = the invariable load

p_1, p_2, p_3 = different independent variable loads

x_1, x_2, x_3, x_4, x_5, x_6 = as in example 3.

All distributions are assumed to be normal. The number N, which gives the relation between the life time of the construction and the interval used to define the d.f. of the variable loads, is here 10. The means and s.d.: s are given in Table 4. The values of k and k′ corresponding to $\alpha = 1{,}8$ have been calculated as before.

Table 3

Quantity / Case	S_{1g}	S_{1p}	x_1	x_2	x_3	x_4
1	0,025/0,5	0,1/1,0	0,02/1,0	0,1/5,0	0,08/1,0	0,15/1,0
2	0,05 /1,0	0,1/1,0	0,02/1,0	0,1/5,0	0,08/1,0	0,15/1,0
3	0,25 /5,0	0,1/1,0	0,02/1,0	0,1/5,0	0,08/1,0	0,15/1,0
4	0,025/0,5	0,2/1,0	0,05/1,0	0,25/5,0	0,08/1,0	0,15/1,0
5	0,05 /1,0	0,2/1,0	0,05/1,0	0,25/5,0	0,08/1,0	0,15/1,0
6	0,25/5,0	0,2/1,0	0,05/1,0	0,25/5,0	0,08/1,0	0,15/1,0
7	0,025/0,5	0,1/1,0	0,02/1,0	0,4/20,0	0,08/1,0	0,15/1,0
8	0,05 /1,0	0,1/1,0	0,02/1,0	0,4/20,0	0,08/1,0	0,15/1,0
9	0,25 /5,0	0,1/1,0	0,02/1,0	0,4/20,0	0,08/1,0	0,15/1,0
10	0,025/0,5	0,2/1,0	0,05/1,0	1,0/20,0	0,08/1,0	0,15/1,0
11	0,05 /1,0	0,2/1,0	0,05/1,0	1,0/20,0	0,08/1,0	0,15/1,0
12	0,25 /5,0	0,2/1,0	0,05/1,0	1,0/20,0	0,08/1,0	0,15/1,0

Quantity / Case	x_5	x_6	k (10^{-6})	k′ $\alpha = 1.90$	k/k′
1	0,0/1,0	0,08/1,0	1,76	1,61	1,09
2	0,0/1,0	0,08/1,0	1,75	1,59	1,10
3	0,0/1,0	0,08/1,0	1,70	1,55	1,10
4	0,0/1,0	0,08/1,0	2,18	2,02	1,08
5	0,0/1,0	0,08/1,0	2,09	1,95	1,07
6	0,0/1,0	0,08/1,0	1,92	1,80	1,05
7	0,0/1,0	0,08/1,0	1,38	1,32	1,05
8	0,0/1,0	0,08/1,0	1,32	1,30	1,02
9	0,0/1,0	0,08/1,0	1,27	1,27	1,00
10	0,0/1,0	0,08/1,0	1,90	1,57	1,21
11	0,0/1,0	0,08/1,0	1,76	1,51	1,17
12	0,0/1,0	0,08/1,0	1,56	1,40	1,11

Analysis of the results.

From the preceding examples we can see that it is possible to define the total safety factors, which correspond to some probability of failure, here $\sim 10^{-6}$. We have also seen that even in the simplest cases this definition is rather complicated and leads to a number of different values. Method 1

Table 4

Quantity / Case	g	p_1	p_2	p_3	x_1	x_2
1	0,05/1,0	0,10/1,0	0,10/1,0	0,10/1,0	0,05/1,0	0,05/1,0
2	0,05/1,0	0,10/1,0	0,10/1,0	0,10/1,0	0,02/1,0	0,02/1,0
3	0,05/1,0	0,10/1,0	0,10/1,0		0,05/1,0	0,05/1,0
4	0,05/1,0	0,10/1,0	0,10/1,0		0,02/1,0	0,02/1,0

Quantity / Case	x_3	x_4	x_5	x_6	k	k' $\alpha = 1.80$	k/k'
1	0,08/1,0	0,50/5,0	0,00/1,0	0,04/0,55	1,39	1,41	0,99
2	0,08/1,0	1,5/10	0,00/1,0	0,04/0,55	1,40	1,22	1,15
3	0,08/1,0	0,50/5,0	0,00/1,0	0,04/0,55	1,55	1,45	1,07
4	0,08/1,0	1,5/10	0,00/1,0	0,04/0,55	1,47	1,24	1,18

seems to have no mathematical justification and Method 2 seems to be much too complicated for practical purposes.

We are now going to compare methods 3 and 4. From (21) it can be seen that, assuming the various u_i values to be equal, we get for $-\beta = 4{,}65$ the relation in Table 5 between α and n. The relation holds good with the conditions given in example 2. If the u_i-values are not equal, the α-value tries to increase.

Table 5

n	1	2	3	4	5	6	7	8
α	4,65	3,29	2,69	2,33	2,08	1,90	1,76	1,65

Tables 3 and 4 show that method 3 gives quite satisfactory results even when the conditions of example 2 do not hold good. However, we can see that with increasing n we get smaller α-values, and also that with very different standard deviations for some essential quantities, the α-values corresponding to $\beta = -4{,}65$ begin to increase.

It does not seem mathematically justified, to use always the same α-values, independent of the structure and other circumstances. It is also impossible to define the α-values separately for all cases.

A compromiss between methods 3 and 4 could perhaps lead to results satisfying the conditions given at the beginning of this paper. Using a computer we could find different α-values for different types of structures, corresponding to e.g.,

- a timber column with normal force
- a prestressed rectangular beam with moment
- a steel column with normal force and moment.

The α -values should be given in standards, and would form a basis for the design of structures. The standard deviations of different factors should also be given in the standards.

Literature:

1 Basler, E. Untersuchungen über den Sicherheitsbegriff von Bauwerken, Diss. ETH Zürich, Nr. 2035, Solothurn 1960

2 Blaut, H. Über den Zusammenhang zwischen Qualität und Sicherheit im Betonbau, München, 1961

3 Bredsdorff, P & Poulsen, E. Om principper ved og krav til dimensioneringsmetoder for baerende konstruktioner, Saertryk af Danmarks Ingeniørakademi 1967.

4 Cramér, H. Mathematical methods of statistics, Uppsala 1945

5 F.I.P.-C.E.B. Empfehlungen zur Berechnung und Ausführung von Spannbetonbauwerken, Deutscher Beton-verein E.V. 1966

6 Freudenthal, A.M. Étude critique des critères de sécurité Huitième Congrès, New York 1968

7 Lloyd, K. & Lipow, M. Reliability: Management, Methods, and Mathematics, USA 1962

8 Paloheimo, E. Om Konstruktioners säkerhet, Nordisk Betong 1966/4

9 Poulsen, E. Jernbetontvaersnits Baereevne, Danmarks Ingeniørakademis publicationer 1967

10 Rüsch, H. Die Sicherheitstheorie. Deutscher Beton-Verein-Arbeitstagung 1959

SUMMARY

Four different design methods are compared, two based on the use of a "total safety factor" and two on the use of "characteristic values". Four examples are treated and it is seen that in these cases the method using "characteristic values" is more reasonable than the other. Some conclusions on the way of determining the characteristic values have also been made.

RESUME

Quatre méthodes d'étude différentes sont comparées, deux méthodes se basent sur l'emploi d'un "facteur total de sécurité" et les deux autres sur l'emploi des "valeurs caractéristiques". Quatre exemples sont traités et l'on y voit que dans ces cas la méthode qui emploie les "valeurs caractéristiques" est plus raisonnable que l'autre. On a tiré aussi quelques conclusions de la façon déterminée des valeurs caractéristiques.

ZUSAMMENFASSUNG

Vier verschiedene Bemessungsmethoden sind verglichen worden, zwei von ihnen gründen sich auf die Verwendung von einem "totalen Sicherheitsfaktor" und zwei auf die Verwendung von "charakteristischen Werten". Vier Beispiele sind behandelt worden und als Ergebnis hat man festgestellt, dass die Methode mit den "charakteristischen Werten" in diesen Fällen zweckmässiger als die anderen sind. Auch einige Schlussfolgerungen über die Art dieser Werte sind gemacht worden.