Some safety problems

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Some Safety Problems

Quelques questions de la sécurité

Einige Fragen zur Sicherheit

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1./ Designations

R	Internal breaking forces and moments
S	Internal forces provoked by load
$Y = R - S$	The Basler reserve
$\xi,\ \eta$	Probability variables
$\xi(t),\ \eta(t)$	Stohastic processes
$a = E(\xi)$	Expectation value
$s = D(\xi)$	Deviation
$v = \frac{s}{a}$	Relative deviation, variation coefficient
$\mu_r = E[(\xi - a)^r]$	Central moment of the r^{th} order
$f = \frac{\mu_3}{s^3}$	Asymmetry
$c = \frac{\mu_4}{s^4} - 3$	Excess
$h = \frac{\mu_5}{s^5}$	Asymmetry of the fifth order
$\frac{1}{k}$	Risk
t	Time
T	Lifetime of the construction
q	Interest factor
W	Cross sectional quantity corresponding to the nature of internal forces and moments
σ	Stress corresponding to the nature of internal forces and moments

$\eta = G(\xi_1, \xi_2, \ldots \xi_n)$	Functional relation of independent probability variables
m	Independent variable of the standardised distribution function
$C(k)$	Cost of rebuilding /the bearing element/
$L(k)$	Annual maintenance cost of the construction /the bearing element/
Q	Sum of the damage caused by the ruin of the construction /the bearing element/, profil lost included

2./ Raising of the problem. Methods applied so far in calculating of dimensions

In dimensioning engineering structures for stability it is most essential to determine safety. The first question to be raised is wether an objective standard of safety can be found and what is the most economical magnitude thereof. Thus the general question of dimensioning is this: In what dimensions should be designed the bearing structure of an engineering construction at a time t = 0, if the construction is being designed for a lifetime t = T, with rebuilding cost of the bearing structure being C, and the annual maintenance cost of the bearing structure being L, sum of damages incurred by the ruin of the bearing structure, profit lost included, being Q.

The classical dimensioning specifications present safety in terms of the magnitude of allowable stress. Allowable stress is an empirical value: it is a quotient of breaking strength and safety. Present time specifications are threefold.

Into the first group come those specifications in which safety manifests itself in the measure of allowable stresses and the grouping of loadings. These specifications show, e.g. three groupings as to the combinations of loading forces: operational loading forces, extraordinary loads, catastrophal loads and influences. To each of the three groupings pertains a different allowable stress.

The second group comprises those specifications in which safety is divided in the grouping of loading forces, the dimensioning stresses and the cross section. These specifications proceed from the ruin of the construction and take every uncertainty, with a divided safety sector, at its proper place into consideration; to a greater relative deviation pertains a higher safety sector, to a smaller one a lower factor. The theoretical basis of these specifications was elucidated by Basler [3].

Specifications that come into the third group calculate safety on the basis of probability theory, with consideration given to loading forces and their deviation, rupture stress and its deviation. These specifications calculate with an undivided safety factor.

Safety factor is determined by a probability of rupture assumed in advance, and probability distribution. The assumption of the probability of rupture /10^{-3}, 10^{-4}, etc./ is a result of subjective evaluation, though it is much more perceptible than saying, that, e.g., a twofold safety is required. The function of the selected distribution is also based on individual judgement. The difference between, e.g., the Weibull and lognormal distribution in the rate of the safety factor can be 10-100 per cent [2].

By means of this procedure are calculated airplanes and solved the dimensioning problems connected with space travel. Theoretical considerations were set forth by Freudenthal [4] [5].

All of the three procedures, though at different places and in various ways, give the rate of safety on the basis of individual deliberation. This rate, the expression of safety, will be further on considered to include failures of an accidental character only.

Safety only provides an objective rate of measurement, as it will be demonstrated further below, together with economical considerations.

3./ A new procedure for dimensioning

The known basic relation for the calculation of dimensions, based on probability theory is, if the time parameter is also considered:

$$\lim_{t \to T} \min \left\{ \left[R(t) - S(t) \right] \geqq 0 \right\} \geqq 1 - \frac{1}{k} \qquad \ldots 1./$$

Expression 1./ says so much in words that, during the lifetime of the construction, the Basler reserve [3] Y/t/ = R/t/–S/t/ must be greater by a probability given in advance /1 – $\frac{1}{k}$/ than zero.

The basic relation is not unequivocal without the time variable t /fig.1./

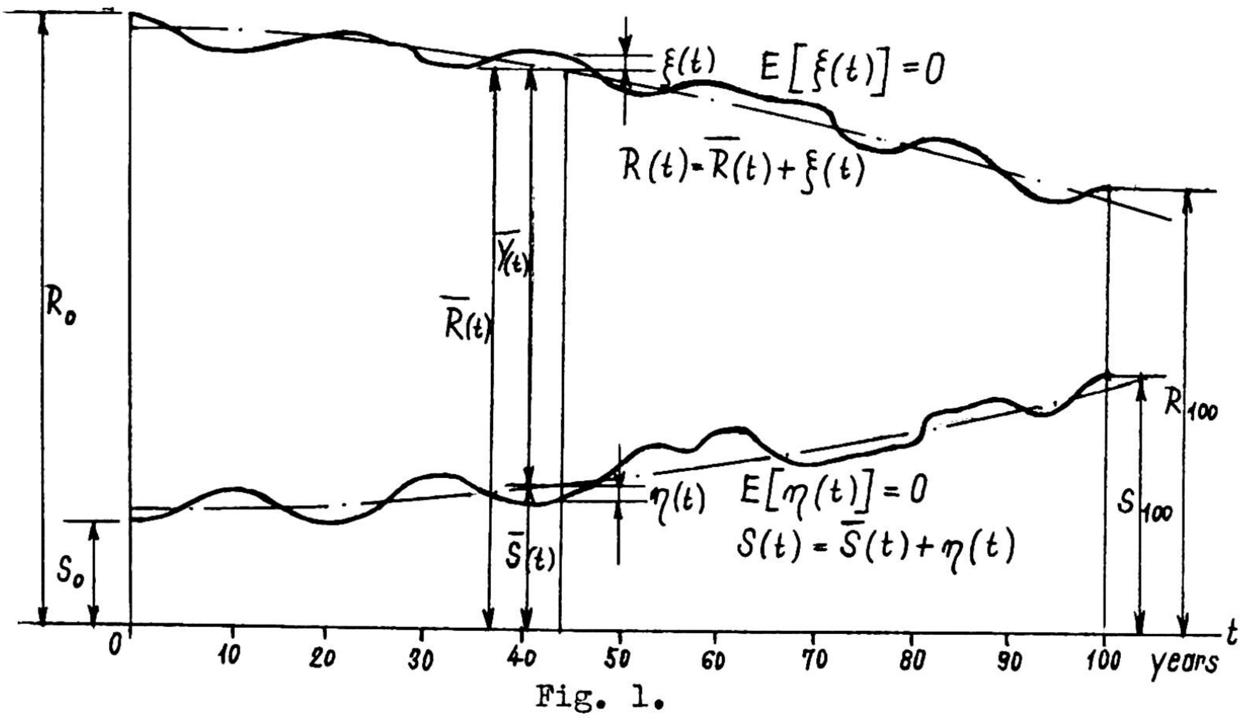

Fig. 1.

4./ Lifetime of the engineering structure

Safety of engineering structures can be related only to a certain lifetime. If T = ∞, the ruin of the structure is considered a certain event. The lifetime of engineering structures, therefore, has to be determined in advance. In respect of lifetime permanent and temporary structures can be dealt with.

For permanent structures lifetime has to be stated in T = 10 years, if it is a vehicle, in T = 100 years if it is an earthwork.

For temporary structures, when an earthwork is concerned, T = 10 years, for structures of locomotion it may be that T = 1. Largely speaking, for permanent structures it is reasonable to count with T = 50 years, for temporary ones with T = 5. From expression 1./ it is perceivable that if T is small, the difference, R/t/-S/t/, is greater than it is for a long T time. This holds particularly if R/t/ and S/t/ are stohastic processes with a notable trend /fig.1/.

5./ Loading forces, loading movements

Loading forces which are constant within time /dead load, earth pressure/, constitute a stohastic multitude, loading forces and movements which vary within time /useful load, water pressure, snow or wind pressure, variation of temperature, creeping, etv./ constitute a stohastic process. The periodical /e.g.annual/ maxima of these latter stohastic processes only form stohastic multitudes. With the processing of technical data it is reasonable to calculate four probability characteristics: the expectation value /a/, deviation /s/, asymmetry /f/ and excess /c/. The processing of the data must be performed on the basis of some textbook of mathematical statistics 1 . In order to provide that the relative deviation of excess itself should not exceed 15 per cent, the number of elements of the multitude has to be selected $\sim$500 at the least. For the determination of the probability characteristics of the useful load it must be proceeded, with consideration given also to future development, from the loading spectre. Forces of a meteorological character must be processed from statistical data.

6./ Rupture stress, geometrical dimensions

Rupture stress within a t time, which constitutes a stohastic process with a trend, has to be determined in principle through precessing a stohastic multitude of rupture tests of the material taken at different times. In want of data it is supposed, in first approximation, that at the end of lifetime rupture stress can be taken as equal to the longtime stress limit and its probability characteristics are the following:

$$\left.\begin{array}{l} \bar{\sigma}_R(T) = \dfrac{\sigma_{Ro}}{\delta} \qquad (e.g.\ \delta = 1{,}15) \\ s^{\sigma}(T) = s^{\sigma}_0\sqrt{\delta}\ ;\quad f^{\sigma}(T) = f^{\sigma}_0\ ;\quad c^{\sigma}(T) = c^{\sigma}_0 \end{array}\right\} \qquad \ldots 2./$$

Geometrical dimensions always display a normal distribution. Because of the corrosion effect the geometrical dimensions have to be diminished at the end of the lifetime by a value Δ , which may be, in absence of statistical data, 1 to 5 per cent of the dimension. Deviation of corrosion is taken equal to deviation of dimension:

$$\left.\begin{array}{l} \bar{\mu}(T) = \bar{\mu}_0 - \Delta \\ s^{\mu}(T) = s^{\mu}_0\sqrt{2}\ ;\quad f^{\mu}(T) = f^{\mu}_0 = 0\ ;\quad c^{\mu}(T) = c^{\mu}_0 = 0 \end{array}\right\} \qquad \ldots 3./$$

7./ Probability characteristics of the function distribution

Probability characteristics of internal forces which cause rupture and internal forces which are the result of loading cannot be determined in a direct way, it is therefore necessary to determine from the probability characteristics of the components the probability characteristics of a quantity characterised by a functional relation. Exact formulation of the problem is this: the independent probability variables $\xi_1, \xi_2, \ldots, \xi_n$ are given, the probability characteristics of these, a_i, s_i, f_i, c_i

/i= 1, 2, ..., n/ are also independent, and $v_i < 0{,}5$; what are the amounts of the probability characteristics of the functional value η, characterised by the functional relation $\eta = G(\xi_1, \xi_2, \dots, \xi_n)$?

If the function η is expanded in a Taylor series and also members of the third order are considered, the probability characteristics of a rational whole function can be determined according to the rule

$$\left.\begin{aligned}
a_\eta &= E(\eta) = G(a_1, a_2, \dots, a_n) + \frac{1}{2}\sum_{i=1}^{n} G_{ii}\, s_i^2 + \dots\dots \\
s_\eta^2 &= D^2(\eta) = \sum_{i=1}^{n} [G_i s_i]^2 + \sum_{i=1}^{n} G_i G_{ii} f_i s_i^3 + \dots\dots \\
f_\eta &= \frac{1}{s_\eta^3}\Big[\sum_{i=1}^{n} G_i^3 f_i s_i^3 + \frac{3}{2}\sum_{i=1}^{n} G_i^2 G_{ii}(c_i+2) s_i^4 + \sum_{\substack{i=1\\ j=1}}^{n} G_i G_j G_{ij} s_i^2 s_j^2 + \dots\dots\Big] \\
c_\eta &= \frac{1}{s_\eta^4}\Big[\sum_{i=1}^{n} G_i^4 (c_i+3) s_i^4 + 6\sum_{\substack{i=1\\ j=1\\ i\neq j}}^{n} (G_i G_j s_i s_j)^2 + \\
&\quad + 2\sum_{i=1}^{n} G_i^3 G_{ii}(h_i - f_i) s_i^5 + 6\sum_{\substack{i=1\\ j=1\\ i\neq j}}^{n} (2 G_i G_{ij} + G_j G_{ii}) G_{ij} f_i s_i^3 s_j^3 + \dots\dots\Big] - 3
\end{aligned}\right\} \quad \dots 4./$$

In expression 4./ e.g.

$$G_{ij} = \left[\frac{\partial^2 G}{\partial \xi_i\, \partial \xi_j}\right]_{\substack{\xi_i = a_i\\ \xi_j = a_j}} \qquad i = j = 1, 2, \dots, n \quad i \neq j$$

Generally if $v_\eta \leqq 0{,}15$, it suffices to calculate with the first, in the case of excess, with the first two members. If $0{,}15 < v_\eta \leqq 0{,}35$, all of the members written here must be counted with.

If $0{,}35 < v_\eta \leqq 0{,}5$ it is necessary to calculate accordingly further members which are not written here. If the derivatives of function G are not limited derivatives but the function can be expanded to a Taylor series at the places a_1, a_2, ..., a_n, also members or an order hidher than the third may be required [6].

If $|f_\eta| < 0{,}1$ and $|c_\eta| \leqq 0{,}2$, the resultant distribution may be considered normal.

8./ Internal forces that cause rupture

They depend in general on rupture stress and cross section quantity and constitute a stohastical series

$$R(t) = \sigma_R(t) \cdot W(t) \qquad \dots 5./$$

or

$$R(t) = H\left[\sigma_R^{(1)}(t),\ \sigma_R^{(2)}(t),\ \mu^{(3)}(t),\ \dots\dots,\ \mu^{(n)}(t)\right] \qquad \dots 6./$$

In expression 5./ internal forces causing rupture can generally be established as a product of rupture stress and cross section quantity. Expression 6./ refers to cases in which the bearing structure is not made of a homogenous material and the type of bearing is such as cannot be separated from the geometrical dimensions of the cross section /e.g. excentrical internal forces within a r.-c, bearer/.

Probability characteristics of internal forces causing a rupture, if calculation has to be made on grounds of expression 5./, are

$$E[R(t)] = \overline{G}_R(t) \cdot \overline{W}(t)$$
$$[v^R(t)]^2 = [v^G(t)]^2 + [v^W(t)]^2 + [v^G(t) \cdot v^W(t)]^2$$
$$f^R(t) = f^G(t)\left[\frac{v^G(t)}{v^R(t)}\right]^3 \qquad \ldots 7./$$
$$c^R(t) = \frac{1}{[v^R(t)]^4}\left\{[c^G(t)+3][v^G(t)]^4 + 3[v^W(t)]^4 + 6[v^G(t) \cdot v^W(t)]^2\right\} - 3$$

If the internal forces producing a rupture are to be calculated by expression 6./, probability characteristics must be determined with the use of formula 4./.

9./ Determination of the cross section quantity

If probability characteristics of the Basler reserve Y/t/ are to be determined from expression 1./, then, on the basis of expression 4./

$$a^Y(t) = \overline{Y}(t) = \overline{R}(t) - \overline{S}(t)$$
$$s^Y(t) = \sqrt{[s^R(t)]^2 + [s^S(t)]^2}$$
$$f^Y(t) = \frac{1}{[s^Y(t)]^3}\left\{f^R(t)[s^R(t)]^3 - f^S(t)[s^S(t)]^3\right\} \qquad \ldots 8./$$
$$c^Y(t) = \frac{1}{[s^Y(t)]^4}\left\{[c^R(t)+3][s^R(t)]^4 + [c^S(t)+3][s^S(t)]^4 + 6[s^R(t) \cdot s^S(t)]^2\right\} - 3$$

From expression 8./ it is to be seen that the dimensioning will be correct if

$$\left.\begin{aligned} R(t) &\geq S(t) + m\, s^Y(t) \\ m &= m(f, c, k) \end{aligned}\right\} \qquad \ldots 9./$$

where

The value of m depends on the selected distribution and the risk given in advance. Before proposing a type of distribution for the determination of the value of m, a simple relation can be given for the cross section quantity at a time t = 0, if internal forces that provoke rupture are such as according to expression 5./

$$W_0 = \Delta W_k + \frac{\overline{S}(T)}{\overline{G}_R(T)} \cdot \frac{1 + m\sqrt{[v^S(T)]^2 + \{1-[m v^S(T)]^2\}\{[v^G(T)]^2 + [v^W(t)]^2\}}}{1 - m^2\{[v^G(T)]^2 + [v^W(T)]^2\}} \qquad \ldots 10./$$

In expression 10./ the surplus cross section quantity, being a result of corrosion, ΔW_k , depends on the value m = m/f,c,k/. S/T/ is the expectation value of the sum of internal forces provoked by loadings, at the end of the service time, $\overline{G}_R$/T/ is the expectation value of the rupture stress of the structural element in question, v/T/ are the final values of the variation factors of the variable quantities.

If internal forces provoking rupture can be calculated by expression 6./, for the determination of the dimensions expression 5./ must be satisfied by way of the trial and error method.

10./ The selected type of distribution

The problem is what kind of a distribution function should be selected for the stohastical process Y/t/ at a time t = T at the end of lifetime or any time t. From among the internal forces caused by loading meteorological forces and movements /internal forces caused by wind, snow, modifications of temperature/ can best be described theoretically with the use of the Weibull distribution [7]. A great part of useful loads and internal forces provoked by dead load do not follow the Weibull distribution pattern. The distribution of cross section dimensions is normal. The type of distribution drawn upon the rupture stress can be treated as though from among a homogenous multitude of bearers a discretional one were selected and given to rupture. This problem is, in its essential conception, an urn-model to which one of the Pearson distributions will best apply. Since in the resultant distribution it is the rupture stress that generally has the greatest part and meteorological forces generally play but a slight part, for a resultant distribution the four parameter Pearson distribution, Pearson IV, can be recommended.

$$\gamma \int_{-\infty}^{m} \frac{e^{-\alpha \operatorname{arctg} \frac{x-d}{g}}}{\left[1+\left(\frac{x-d}{g}\right)^2\right]^\beta} dx = 1-\frac{1}{k} \qquad -\infty < x < +\infty \quad g>0 \quad \beta>\frac{1}{2} \qquad \text{...11./}$$

The Pearson IV. distribution which is interpreted between $-\infty < x < +\infty$ is not suitable because effective distribution is no clear urn model and, because distribution is dimensioned only for $x>0$. If the four probability characteristics of distribution, $a^Y/t/$, $s^Y/t/$, $f^Y/t/$, $c^Y/t/$ are given, β, α, d and g can be determined. The value of γ can be determined from the condition that the integral of expression 11./ between $-\infty$ and $+\infty$ is [1].

$$\left.\begin{aligned} &\nu = 6\,\frac{c^Y+2-(f^Y)^2}{2c^Y-3(f^Y)^2} \quad \text{auxiliary quantity} \\ &\beta = \frac{\nu}{2}+1 \\ &\alpha = f^Y\cdot\nu(\nu-2)\sqrt{\frac{1}{16(\nu-1)-(f^Y)^2(\nu-2)^2}} \\ &g = \sqrt{\frac{\nu-1}{\alpha^2+\nu^2}}\;\nu\, s^Y; \quad d = a^Y-\frac{g\alpha}{\nu} \\ &\gamma = \frac{1}{\int_{-\pi/2}^{+\pi/2} e^{-\alpha z}\cos^\nu z\,dz} \end{aligned}\right\} \qquad \text{...12./}$$

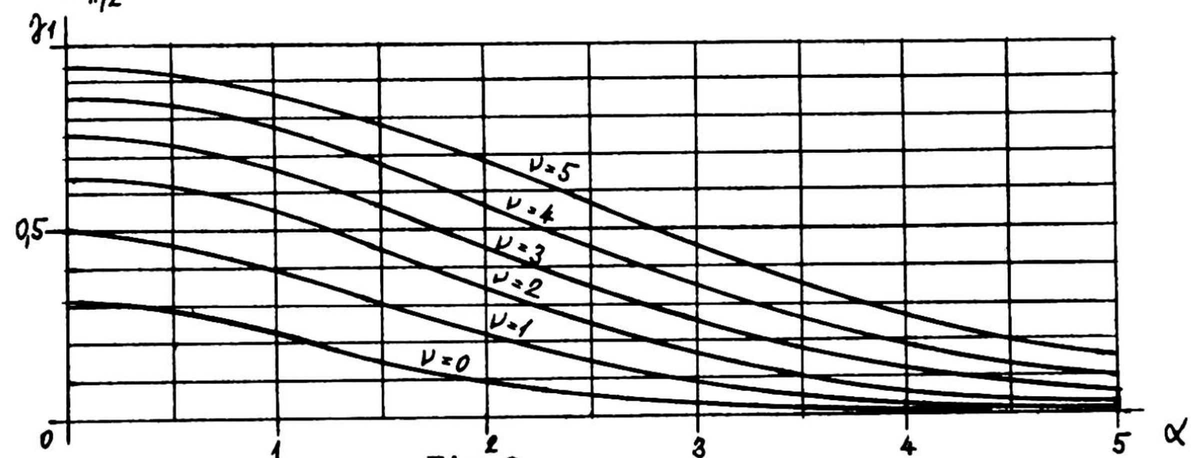

Fig.2.

From expression 12./ numerous conditions present themselves for the distribution characteristics which are not dealt with in this paper. The values of γ for whole number values of α and ν are shown in figur 2.

11./ Optimum risk

The value of m = m/f,c,k/ has furthermore to be determined in expression 10./ in order that the cross section quantity could be determined. The determination from expression 11./ is unequivocal if the value of k is given. For the determination of k two conditions can be offered.

The first condition is that the total cost of the installation should be a minimum. Supposing the interest factor to be q, the cost of rebuilding of the installation, C/k/, must be written off, during a service time T, and it is assumed that the installation will be ruined after a time t<T and the part of the construction not yet written off at that time will be capitalised to the date of the ruin. Then the total cost will be

$$K_{(k)} = C_{(k)} + \frac{1}{k}\left\{C_{(k)}\left[1+\frac{q^T-q^t}{q^T-1}\right]+Q\right\} \qquad \ldots 13./$$

A minimum cost can occur where the first derivative by k of expression 13./ is zero.

The costs of the bearing structure increase in a linear way with the cross section quantity, C/k/ = A+BW . This linearity will hold if the cross section quantity represents an area or if the ratio of cross section modulus to radius of inertia is constant. If expression 10./ is expanded to a series, it will hold, with a good approximation, that $W_0 \cong W' + wm$.

If f, c and s are constant, for the thinkable values of k, $m = \lambda_0 + \lambda_1 \log k$. A deeper reason for linearity is to be found in the fact that distribution functions generally are exponential /For a normal distribution e.g. between 2<log k<6, it is true with a 3 per cent accuracy that m = 1,22+0,6 log k/. Substituting the above expressions into eachother, $C/k/=/A+BW'+B\lambda_0 w/+ +B\lambda_1 w \log k$ that is

$$C_{(k)} = C_0(1+b_1 \log k) \qquad \ldots 14./$$

Expression 14./ reflects a stohastic relation which can be verified for a series of numerical examples with a difference less than 2 per cent, doing regressional calculations. The minimum that results from expressions 13./ and 14./ is

$$k(t) = \frac{1+b_1 \log \frac{k}{e}}{b_1 \log e}\left[\frac{Q}{C\left(\frac{k}{e}\right)}\left(1+\frac{q^T-q^t}{q^T-1}\right)\right] \qquad \ldots 15./$$

The maximum for expression 15./ produces itself at a time t=0. On an average, if the cost of the bearing structure of a building based on a 3 per cent risk, is C,

$$k_{max} \cong \frac{2,6}{b_1}\left[\frac{Q}{C}+2\right] \qquad \ldots 16./$$

It is apparent from expression 16./ that the more damage will be caused by the installation when it is ruined, the less will be the risk permitted to be taken. E.g. if T = 1 and Q = 0, $k_{min} \sim 50$. If T = 50 and $\frac{Q}{C}$ = 100, $k_{max} \cong 5000$. Here the risk that is taken, varying within a range of 2 per cent and 0,02 per cent, corresponds to the percentage wastes in non damaging industrial production, which is 1-2 per cent [8].

Another condition is that the annual quotient to write off for the installation is $\frac{q^T/q-1/}{q^T-1}$ C/k/ and the total of annual maintenance, L/k/ is the minimum of what is referred to as entire cost. The concept of entire cost was defined by a Congress held on "Perspective of the user and reliability of the system" in the United States in 1962. It is assumed that maintenance costs take the sum of

$$L(k) = L_0\left(1+\frac{b_2}{\log k}\right) \qquad \ldots 17./$$

Expression 17./ is not proved, it merely appears to be logícal upon the analogy of expression 14./ [9]. The minimum of all anual costs is secured by the expression

$$k = 10^{\sqrt{\frac{L_0 b_2 (q^T-1)}{C_0 b_1 q^T (q-1)}}} \qquad \ldots 18./$$

being satisfied. Expression 17./, if $T \sim 50$ and $q-1 = \frac{p}{100}$ where p, in percentage, is the interest rate, will be

$$k \cong 10^{9,5\sqrt{\frac{L_0 b_2}{C_0 b_1 p}}} \qquad \ldots 19./$$

From the two expressions /15./ and 18./ that one must be satisfied which gives a larger value for k. From the comparison of expressions 14./ and 19./ results that when the condition

$$\frac{Q}{C} \geqq \frac{b_1}{2,6}\, 10^{9,5\sqrt{\frac{L_0 b_2}{C_0 b_1 p}}} - 2 \qquad \ldots 20./$$

is satified, that is, if the ratio of the damage incurred and the rebuilding costs is greater than the right side of expression 20./, the value of k must be determined on the basis of expression 15./ and /or 16./, if it is smaller, expressions 18./ and/ or 19./ will give the value of k.

It should be noted that in the vicinity of the optimum value for extremely small differences will result in expression 13./, therefore the value of k must be determined with a rounding up and on a rather large scale.

12./ Other probabilities that may be considered

Beside what has been said above it is also essential, how many uniform structural elements are going to be built in. If n number of bearing elements are to be fabricated and a risk of $\frac{1}{k}$ has to be taken for each of them, for one piece a risk of $\frac{1}{k'} < \frac{1}{k}$ must only be taken. The solution of the problem is

$$1-\frac{1}{k} = \binom{n}{0}\left(\frac{1}{k'}\right)^0\left(1-\frac{1}{k'}\right)^n \qquad \ldots 21./$$

Eypression 21./ displays a binomial distribution.

$$\left.\begin{aligned} k' &= \frac{1}{1-\sqrt[n]{1-\frac{1}{k}}} \\ \text{and/or} \quad k &= \frac{1}{1-\left(1-\frac{1}{k'}\right)^n} \end{aligned}\right\} \qquad \ldots 22./$$

If $k > 50$, then, with a good approximation

$$k' \cong nk \qquad \ldots 23./$$

Thus, if it is required that no one of the n pieces should get ruined with a probability of $\frac{1}{k}$, every piece must be fabricated with a risk of $\frac{1}{nk}$ being taken.

13./ Conclusions

1./ The following answer can be given to the problem raised: The correct dimensions are given in expressions 9./ or 10./, the value of m = m /f, c, k/ can be determined through the Pearson IV. distribution according to expression 11./, the most economical measure of risk taken against failure, 1/k, is given by expressions 16/ or 19./. As to the measure of the assumed risk it must furthermore be considered, how many uniform elements in question are going to be fabricated.

The suggested method of calculation does not contain any subjective factors, all dimensions and safety can - on the basis of mathematical statistics - be determined solely upon economical considerations.

2./ Safety, consequently, is a mutual and unequivocal function of the probabilities for the installation that during its scheduled service time all circumstances provoking ruin can occur simultaneously in the most possibly unfavourable arrangement [3].

The lower this probability /the risk taken/ is, the greater is the safety. We suggest the acceptance, as a measuring value, of $\log k$ the logarythm of the reciprocal value of the risk taken. This expression has proved suitable in information theory [10], as a quantity proportional to the measuring number of the information quantity. For a great safety a large amount of information is required about the given bearer. Investment expenditures increase with safety, maintenance costs decrease with it.

3./ For our bearing structures the principle of equal safety is in appropriate. The more damage is caused by the structure with its ruin, with so much more safety must it be designed. Secondary bearers, the ruin of which causes no damage, must be designed with a lesser safety. Installation with a short designed service time can be of smaller divisions, because within a shorter period the rupture strength of the load-bearing building material shows a lesser decrease and the probability for the occurrence of the loads, particularly meteorological ones, is lower within a shorter period.Consequently, if it is to proceed from the safety of the primary system of bearers of definite installations, the primary system of bearers of temporary installations can be fabricated with a lesser safety and so can the secondary bearers of the definite installations. Still lesser safety is required for secondary bearers of temporary installations.

4./ General rules for dimensioning are provided by deterministic interrelations in technical mechanics. By reason of a deviation of parameters in the functional interrelations the economical dimensions have to be determined with the aid of stohastic interrelations based on probability theory.

5./ A processing of statistical data is required. The described method, however, can be applied even without processing the data, in that case it has to be proceeded from loading given in the rules and from nominal geometrical and strength measures. For deviations there is to be taken, in the absence of data, one half of the tolerance. Tolerance, then, is based on statistical experience.

6./ Author considers the application of this procedure absolutely necessary: in setting up rules for dimensioning, stability calculations for elements of serial production and structures of high cost.

7./ Rules in operation at present are over-dimensioned even today. The degree of over-dimensionedness is, with various rules, in terms of costs 8-12 per cent for primary bearers at definite installations. Over-dimensionedness for secondary bearers and for temporary installations is 11-17 per cent. This can best be helped if calculations will be made, instead of the minimum values as specified in the rules, with their expectation values. If this proportion is considered, there will result economical dimensions /E.g. the expectable value of the yield point of St. 37 is, on the basis of statistical data, [11] ~ 2800 kp per square cm, whereas the rule specifies 2400 kp per square cm.

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Summary.

From all factors influencing the dimensions /loading, geometrical dimensions, crushing stress, etc./ the value and the probability variables of the load capacity reserve, Y/t/, can be determined. By means of the Pearson IV. distribution the geometrical dimensions can be determined for a risk arbitrarily undertaken.The undertaken risk can be determined through only economical conside-

rations. The greater the damage caused, the lesser risk should be undertaken. If the damages are not significant, dimensions are influenced by the annual maintenance costs, /L/. For a safety rate the logarithm of the reciprocal value of risk /log k/ is suggested.

RÉSUMÉ

La valeur de la réserve de limite admissible de la charge, Y/t/, et ses variables de probabilité peuvent être déterminés à l'aide de tous les facteurs qui sont à même d'influencer les dimensions - tels la charge, les dimensions géométriques, tensions de rupture, etc. Par moyen de la distribution Pearson IV. les dimensions géométriques peuvent s'établir pour un risque arbitrairement entrepris. Or, le risque entrepris peut être déterminé moyennant des seules considérations économiques. Plus le dégât est grand, moins de risque doit être entrepris. Si le dégât n'est pas important, les dimensions seront influencées par les frais annuels d'entretien. Proposition est faite d'employer, pour mesure de sécurité, le logarithme de la valeur réciproque de la risque entreprise (log k).

ZUSAMMENFASSUNG

Aus sämtlichen, die Abmessungen beeinflussenden Faktoren - wie Belastung, geometrische Abmessungen, Bruchspannungen usw. - können der Wert Y/t/ der Belastungsfähigkeitsreserve und seine Wahrscheinlichkeitsveränderlichen berechnet werden. Mit Hilfe der Verteilung Pearson IV. können die geometrischen Abmessungen zu einem beliebig unternommenen Risiko bestimmt werden. Das unternommene Risiko kann wieder auf Grund allein wirtschaftlicher Betrachtungen festgelegt werden. Je grösser der Schaden, ein um so niedrigeres Risiko darf unternommen werden. Bei nicht bedeutendem Schaden beeinflussen die jährlichen Wartungskosten, /L/, die Abmessungen. Als Sicherheitsmass wird der Logarithmus des Kehrwertes des unternommenen Risikos vorgeschlagen (log k).