So far as the static properties are concerned, the destructive tests are not necessarily the most suitable routine for a design.

As mentioned heretofore, the purpose of such test is to obtain some kind of “ultimate” data to be used in a design. These tests are therefore directly connected with the present design philosophy which exacts such information. Traditionally, engineers use the safety factor, which is determined by no other criterion than experience, to prevent the designed object from reaching the ultimate state. However, when the ultimate data have been, say, halved, i.e., with a safety factor of two, they can no longer represent the ultimate state, from which they were derived. In fact since only the “halved” values are useful in the design it is quite logical to obtain them directly in the routine tests without doing any destructive effects to the specimens. The foregoing discussion of course apply only to a design which is expected to be safe during its service life.

Many destructive tests can, as a consequence of the new approach to design problems, be easily modified to become non-destructive ones. The only difference between them is on the application of test loading. In the usual tests the ultimate loads are applied finally. Now since such ultimate data are no longer a necessity in every case, only a test “working” load with due allowance for possible variation is sufficient to furnish information about the future safe behavior of a material.

These nondamaging tests not only can be used in the design stage, but also be employed for checking the designed object after it comes into being. Such checking is possible because all the variations other than the variability of applied loads have been taken into account and liquidated in the design. The partial safety factor, i.e., the safety factor without any allowance for loading variation, is therefore a known quantity corresponding to a given probability of safety. Such tests should confirm the design assumptions and can provide valuable data for the investigation of the probability of safety.

Concluding Remarks

(1) The normal practice of the material manufacturers at present is merely to supply information on the mean values of the required quantities. It is evident from the examples that the variabilities of the required quantities are equally important, and should also be provided by the manufacturers. Furthermore, a material of good quality should be signified not only by its high or low values of a certain properties but also by the smallness of its standard deviation.

(2) Once the variabilities or the standard deviations are available an object can be designed to correspond to a specific probability of safety. On the other hand, with sufficient knowledge of the standard deviation and the variabilities, the probability of safety of the existing design can be assessed and its service life estimated.

(3) The proposed definition of the safety factor indicates its true content clearly. An important feature of such definition is the inclusion of the statistical concept, which enables the suggested method of design to give a more economic result than the conventional method with same limiting conditions.

(4) Either plastic or the elastic state can be chosen as the limiting condition, i.e., the limit of the serviceable condition. Since most of the designed objects are expected to behave safely and not to “yield” during their service life, the plastic method of design seems to have been over-glorified and can in fact only play a role in fail-safe design or wherever a plastic flow is expected. The factor of safety offered by the plastic method is only a factor of ignorance, to which hardly any scientific inference can be attached.

(5) In certain complicated cases, the vigorous stress analysis is prohibitive, the alternative is to analyze the object in question by a simple method and to introduce a suitable variability due to the inaccuracy to be included in the safety factor. A designer can thus have full control over the design through the flexible use of the safety limits, variabilities, and the safety factor, all of which can be controlled and adjusted to match the role any component plays in the whole assembly.

Bibliography


DISCUSSION

L. E. Iversen

The paper should be a valuable contribution to the science of predicting failures inasmuch as it appears to be the first to treat the problem with more than two statistical variables based on the static failure criterion (for two variables see R. B. McCallay, Jr., “Nomogram for Section of Safety Factors,” Design News, September 1, 1957).

Some numerical errors appear on page 389, right-hand column:
1. line 10 and 11 should read:
   $h^2 = \frac{1}{2h} \times 0.1235 \times 0.1 \times 2.5^2 \times 12^2 \times 6 = 2.38,$
   $h = 1.54$ in.
2. line 27 should read:
   Then, with $\gamma_s = 0.20$,
3. line 32 should read:
   $h^2 = \frac{1.84}{35} \times 0.741 \times 0.08 \times 2.5^2 \times 12^2 = 2.81, h = 1.68$ in.


A serious objection to this paper is that it treats the failure problem from a static viewpoint. This is unfortunate since almost all structures fail as a result of variable loading, variable temperature, etc., and cumulative damage. The following papers treat these problems:

2. A. Ferro and R. Colombo, “An Analysis of the Probability of

1 Design Analysis Section, Construction Equipment Engineering Department, International Harvester Company, Moline, Ill.
Author’s Closure

Mr. Iversen has raised several interesting points. The numerical errors, although unnecessary, did not damage the examples, which were to show the procedure of the statistical maneuver.

It should be emphasized that the physical equations expressing the relationship between \( R \) and \( Q \) in terms of their independent arguments are not necessarily “static.” The adjective “physical” obviously implies a great variety of problems, and such equations can even be, say, optical or electrical in nature. It was only for the convenience of heavily occupied readers that the simple static cases were chosen as examples.

The literature mentioned by Mr. Iversen is valuable and familiar to readers in this field. There is a fundamental difference between the approach adopted by these workers and that employed in the paper. The present approach is focused on the design problem, which involves many other parameters than the pure physical ones, such as statistical (in its narrow sense), economical, and even aesthetical. The investigation of the previous workers is only concerned with the explanation of physical phenomena and the establishment of their governing equations, which only form a facet of the design problem.

As to the frequency functions, it should be noted that the proposed method is nonparametric. Although the upper and the lower bound of the probability of safety given by Tchebycheff’s inequality are of great practical value, Table 1 was also intended to show the qualitative perspective of the proposed “safety” concept. Frequency functions for any particular case are of course useful. However, at the very moment, there are more important problems in design philosophy which should have priority.