Critical appraisal of safety criteria and their basic concepts

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Etude critique des critères de sécurité et de leurs fondements conceptuels

Kritische Betrachtung der Sicherheitskriterien und ihrer grundsätzlichen Auffassungen

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In his brilliant survey of the present status of structural safety problems Professor Freudenthal makes clear that engineers are not designing structures close enough to the "state of art" limit, that the rational approach to the problem of safety has to be a probabilistic one, and that absolute safety is no more than a convenient fiction.

The key to a rational approach to structural safety is in his own words the concept of an "acceptable risk of failure". But most engineers, because they believe they can or they have to design absolutely safe structures, are reluctant to accept such a concept.

The difference between the attitude of accepting or not accepting a risk of failure, be it a small one, is not an academic question, because structures will be designed quite differently depending on whether one does or does not recognize the impracticability of building absolutely safe structures. The consequences of these two opposite attitudes seem worthwhile emphasizing.

If the existence of risks is to be recognized, accepted and taken into consideration in the design of engineering structures, instead of trying to have uniform safety in all elements of a structure - which is an ideal recommended by several authors - one has to reduce the strength of the elements of which the failure will have less costly consequences, with a view to reinforcing those elements of which the failure would have costlier consequences. Such criteria will enable the design to be improved without increase in cost.

If the existence of risks is to be taken into consideration, one has to adjust the strength of the whole structure to the consequences of possible failures.

This implies building a dam, if located upstream of a town, stronger than one located downstream, even if both dams could otherwise be built perfectly alike.

If the existence of risks is recognized and accepted, the structure should be designed so as to reduce as much as possible the consequences of accidents. There will even be instances where it may be convenient to increase the probability of failure of a structure so as to reduce its cost, the savings being used to minimize the consequences of a possible failure. This will be the case with dykes against floods and sea invasions, where transverse dykes are built using the money that could otherwise be used to increase the height and reinforce the main dyke. The function of the transverse dykes is the reduction of the area flooded in case of failure of the main dyke rather than direct protection against sea invasion.

If the existence of risks is to be recognized and taken into consideration, structures will have to be designed so as to fail in the less inconvenient way. In some cases this will imply the use of devices similar in function to fuses, for instance when a lighter and lower dam is built on a secondary valley as a protection to a big earth or rock-fill dam on the main valley.

In spite of Professor Freudenthal's well presented arguments against redundant elements, the presence of such elements can, in some particular cases, contribute to increase the safety of the structure. Not only can the failure of redundant elements give warning to halt operation and avoid serious consequences of accidents, but in some other cases the presence of redundant elements will avoid complete collapse, that would, otherwise, have catastrophic consequences.

Some structures are intended to absorb energy rather than to hold forces.The amount of energy consumed in the destruction of redundant elements can, at least in some cases, be sufficient to save the structure. This is apparently the main reason why ships are always moored with a large number of redundant cables, instead of with a few strong cables.

SUMMARY

The need to design structures accepting the existence of risks and taking into account the possible consequences of accidents may, or may not, be recognized. The practical implications of one or the other attitude are quite different.

If the existence of risks is recognized, the adoption of an uniform safety factor for all the elements of a structure, and the adoption of the same safety factor for structures submitted to the same loads but whose failure can have different consequences, should be discontinued.

It is also pointed out how redundant elements can contribute to increase the overall safety of a structure.

RÉSUMÉ

Reconnaître ou ne pas reconnaître l'impossibilité de sécurité absolue quand on projècte une structure peut avoir des conséquences pratiques très différentes.

Si cette impossibilité est reconnue, on doit choisir le coefficient de sécurité de chaque élément d'une structure, et de chaque structure en elle-même, d'après les conséquences des possibles accidents.

L'influence des éléments superabondants sur la sécurité d'une structure hyperstatique est aussi discutée.

ZUSAMMENFASSUNG

Sehr verschiedene praktische Folgerungen beruhen auf dem Erkennen bzw. Nichterkennen der Möglichkeit, Tragwerke mit Ausschluss aller Risiken zu entwerfen.

Wenn das Bestehen von Risiken erkannt wird, muss der Sicherheitskoeffizient für jedes Element des Tragwerkes sowie das Tragwerk an sich nach dem Umfang der Folgen eventueller Unfälle gewählt werden, anstatt der üblichen Wahl von genormten Sicherheitskoeffizienten.

Der Einfluss der Verwendung zusätzlicher konstruktiver Elemente zur Erhöhung der Sicherheit von statisch unbestimmten Tragwerkssystemen wird ebenfalls beleuchtet.

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