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Summary Report on Theme V

Rapport sommaire au thème V

Zusammenfassender Bericht zum Thema V

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1 - INTRODUCTION

Important advantages would derive from the use of the same basic framework for studying different Civil Engineering reliability problems.

This framework should be sufficiently general to be usable in many types of problems: serviceability and ultimate limit states; permanent and variable loads, repeated loadings leading to low cycle or high cycle fatigue; cyclic, stochastic, and other types of load variability in time; load combinations; imposed deformations of all kinds; mechanical properties corresponding to linear and non-linear behaviour; deterioration; variability of dimensions, etc.

The study of these problems requires theorizations of the phenomena and, consequently, the choice of pertinent variables. Statistical distribution functions should be associated with the variables. The main reliability problem consists in determining the probability of a given limit state being reached in a certain interval of time.

Several general formulations of the above problem have recently been proposed. Yet most of them do not explicitly indicate how to deal with load repetition.

2 - REVIEW OF THE CONTRIBUTIONS TO THE SYMPOSIUM

In the paper by Sandi (1), loadings are taken as basic variables. A metric is introduced in the space of these variables (Hilbert space) through the concept of elastic work. Limit-state conditions are represented by statistical distributions in the same space. The convolution of the densities of probability of loadings with the distribution functions of limit-state conditions yields the probability of survival. Suggestions are presented in the paper on how to simplify the computation of convolution integrals and on how to generalize the concepts of characteristic and design values usually applied in one--variable problems. According to the author, the way he suggests to deal with variable loads could simplify the formulation of repeated loading problems. Although the paper contains many inspiring ideas, it is difficult to anticipate how some of them could be implemented.

The contribution by Paloheimo (2) is not directly related to repeated loading. A set of influencing parameters of any nature is considered. For checking safety, the fractile of each parameter is weighed in accordance with its influence on the variability of the limit-state condition. This procedure can be considered as an improvement of the methods based on characteristic values. Paloheimo's method allows to determine fractiles of any multi-variable function. It is worth studying owing to its possible application in a large variety of situations.

Schueller (3) specifically dealing with fatigue problems advocates a two--parameters Weibull distribution to idealize fatigue lives derived from tests of materials, components, and structures.

Tichý and Vorlíček (4) call attention to the need of correctly interpreting low-cycle repeated loading tests by representing probabilities of failure by a continuous distribution function in the first cycle, and by discrete probabilities in the following cycles.

Freudenthal (5) criticizes the Introductory Report and states that the safety concepts used for single load applications cannot be generalized to repeated loading cases. According to Freudenthal, limit state design and repeated loading design are different but complementary aspects of design. In this splitting of design problems Freudenthal has in mind the extreme cases of high-cycle fatigue and single loading, disregarding all other types of load repetitions, which very frequently occur in Civil Engineering situations. Usually, loads are not applied once only, and they are not sufficiently repeated to produce high-cycle fatigue. Decay due to a small number of large amplitude cycles is important in several situations and should be taken into account. The suggested classification of structures according to the ratio of the risk of fatigue failure to ultimate load failure simply means that the prevalent loading condition (the one leading to a probability of failure considerably exceeding the others) should be considered in the design.

The Reporter maintains his point of view on the need of formulating and implementing general reliability concepts covering different types of loading, behaviour and limit-state conditions in the same framework.

Kuesel (6) draws attention to the fact that, in several cases, design should be based on deformability limit-states, which should take into account repeated deformations. Such is the case of earthquake loading. These concepts are exemplified by the design of underground (tunnels) and aboveground (pier shafts) structures in San Francisco Area Rapid Transit.

The Reporter fully agrees with the point of view that earthquake design should be based on ultimate deformability as a limit-state criterion and has had opportunity to say so in several occasions ((7) and (8)). It can even be mentioned that one of the main reasons for organizing this Symposium was to discuss this problem and explicitly to deal with ultimate deformability in structures acted by repeated loading.

The above mentioned papers deal with general problems. Some of the other papers included in the Preliminary Report deal with special types of structural elements. Thus, Allen and Dalgliesh (9) discuss the reliability of of steel and glass cladding. Their general conclusion is that limit-state conditions are influenced but little by the rate of loading.

The paper by Maeda (10) indicates how to compute the probabilities of static and fatigue failures in main girders of steel highway bridges subjected to traffic loads. Miner's rule of damage accumulation is used on base of statistical idealizations of traffic loading and fatigue strength of steel.

Bosshard and Raukko (11) summarize numerical studies on buckling of steel columns under stochastic loading using a stress-strain diagram of steel idealizing Bauschinger effect. The paper is merely introductory and no conclusions are drawn.

Davies (12) studies the shakedown of plane steel frames, a problem which the Reporter considers outside the scope of Theme V.

Although dealing also with plastic shakedown, Augusti and Baratta (13) assume a stochastic distribution of local strengths. A numerical example indicates how to compute bounds of shakedown probability.

Finally Abeles (14) refers to several problems of resistance in pre-stressed concrete design and discusses the validity of Miner's hypothesis.

This short review shows that the papers included in the Preliminary Report deal with many different subjects. This is not surprising the scope "safety in repeated loading" being very wide. The same variety of present-ations occurred during the discussion of Theme V.

Among the papers on repeated loading presented in the free discussion, a special reference is due to the contributions by Viest, Eggert and Tilly, dealing with energy absorption capacity of steel structures, safety of bridge bearings, and differences between repeated stresses and repeated strains, respectively.

3 - CONCLUSIONS

In Civil Engineering a large amount of research has recently been directed to repeated loading. Yet it is not clear how the information thus obtained is going to be introduced in design practice, particularly in design codes.

A rational design method should cover:i) an idealization of loads including their repetitions and combination; ii) a definition of limit-states depending on internal state variables related to repetitions, and iii) a reliability theory for dealing with these concepts. This framework exists and is widely used in very particular cases such as high-cycle fatigue under cyclic loading.

Satisfactory solutions are not yet available for problems involving a small number of large amplitude load repetitions (forces or imposed deform-ations) leading to deterioration phenomena.Typical cases are steel structures alternatively under tension and buckling, and reinforced concrete elements under alternative bending, associated with considerable compressions, and under alternative shear. The importance of these situations e.g. in earth-quake resistant design is paramount. Design rules considering these situations should be implemented. Repeated loading being the general case, its substitution in design by monotonic loading is only acceptable in particular cases.

Progress in this field should be achieved by: i) contributions oriented to fundamental theoretical aspects, such as general reliability theories; ii) idealizations of loadings, limit-states, and structural behaviour, including load repetitions; and iii) experimental studies on the mechanical properties of materials and behaviour of structural elements, structures and parts of structures. The information thus obtained should be integrated and implemented in design rules.

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SUMMARY

The contributions to Theme V are briefly reviewed. The importance of the repeated loading problem and the need to introduce in design practice information gained by recent research in this field are emphasized. Lines of progress are suggested.

RESUME

Les contributions au thème V sont brièvement commentées. On relève l'importance du problème des charges répétées et la nécessité d'introduire dans la pratique des informations recueillies par des recherches récentes. On donne des directives pour la réalisation de progrès.

ZUSAMMENFASSUNG

Die Beiträge zum Thema V werden kurz kommentiert. Die Bedeutung des Problems wiederholter Lasten und die Notwendigkeit, in der Praxis die neuesten Erfahrungen auf diesem Gebiet zur Geltung zu bringen, werden hervorgehoben. Es werden Richtlinien für diesbezügliche Fortschritte vorgeschlagen.

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