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Applications of Statistics and Probability

Civil Engineering Reliability and Risk Analysis

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Synthesis of Session 9b: Random processes, geostatistical methods: Reliability analysis

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SUMMARY REPORT

This session concentrated on certain aspects of uncertain loading and system properties of mechanical systems and on deteriorating resistance properties.

The contribution by V. Bagdonavičius and M. Nikulin on "*Accelerated life models for systems and their components*" addressed a subject area not yet very developed in materials science. Appropriate models are crucial when structural components are degrading with time under stress or other actions and when no physical model exists for the particular degradation phenomenon. Only under unfavorable test conditions sufficient data can be collected for components fairly durable under normal operating conditions. The authors introduce various types of models and classify them according to mathematical criteria. The models include the power rule model, the Arrhenius model and the Eyring model together with reliability functions of the Weibull, log-logistic, log-normal and generalized probit type. General estimation procedures are presented and asymptotic standard errors are given. Some generalizations towards multivariate models are proposed.

D. Bryja, R. Sieniawska and P. Sniady "*First crossing problem of suspension bridge being fatigue-degraded*" introduce three types of failures, i.e. firstly, the first passage failure with a possibly reduced strength, secondly, the failure due to a jump of the time-variant strength residual function below the action effect and thirdly, the decrease of the residual strength function and the action effect below a threshold value. All failure types are assumed to be mutually exclusive. The corresponding crossing rates are determined and summed up. This is an interesting hypothesis. The residual strength function is a function with discrete decrements presumeably occurring at each load pulses. This is an interesting hypothesis. One certainly can argue whether the last two failure modes are realistic and/or the corresponding material parameters can be determined by tests. It is generally believed that the strength degradation processes, at least for high cycle fatigue, result in a smooth residual strength function as a result of a very large number of very small damage increments. Otherwise dependance between action effect and strength decrement is introduced but is not considered in the paper. Nevertheless, some studies show the influence of various parameters on upcrossing rates and life time failure probabilities.

The second group of four papers is concerned with the reliability analysis of earthquake or otherwise excited structures with special emphasis on the effect of system uncertainties. P. Venini "*Stochastic control of continuous uncertain structures*" investigates the possibility of active control for systems with uncertain properties such as Young's modules and mass density using standard procedures for prediction and control based on the energy in the system. The author can show that there is a pronounced difference in the variances of displacements and velocities with or without system uncertainties and with and without control. The author proposes a numerical solution to the problem. A first numerical example illustrates the capabilities of the method.

H. U. Köylüoğlu & A. S. Çakmak and S. R. Nielsen in "*Reliability approximations for MDOF structures with random properties subject to random dynamic excitation in modal subspaces*" propose to analyze the reliability of uncertain (stiffnesses and dampings) MDOF-systems in modal subspaces by making use of classical results for the upcrossings of scalar or vector processes into their respective failure domains such as rectan-

gles or inscribing and circumscribing circles. A mapping from the modal space into a space of locally scalar problems is required. The resulting surface integrals are computed numerically. The authors can show at an example that only the few first modes need to be considered. The unconditional failure probabilities obtained from conditional crossing rates are determined by simple Monte Carlo simulation. The method can provide bounds of varying sharpness and further work is needed to identify the best type of bounds and the best way of simplifying the problem which is complicated and computationally very expensive by its very nature as was pointed out in the discussions. Some thought is given to modal correlations.

A similar subject was investigated by P. Orsero in *"A statistical modal approach for the frequency response of complex structures"*. Uncertain system properties are described by means and variances for three simple types of probability density functions. The effect of uncertainties on the responses in the frequency domain is investigated showing considerable sensitivity. In general, the frequency responses show larger band width when system uncertainties are present. In the discussions it was pointed out that the frequency responses in different modes must be highly correlated due to common sources of uncertainties.

The important question of random inhomogeneities in shear layers on hard ground and excited at their base was addressed by F. Toubalem, F. Thouverez and P. Labbé in *"Contribution in the study of a transfer function in a medium with random characteristics"* in a theoretical study. By certain variable transforms it was possible to describe original problem by a Helmholtz equation with stochastic coefficients which turned out to have an analytical solution under certain conditions. The stochastic model for the pertubations in the system properties is appearently assumed to be white noise. The solution found compares well to results in the literature. The concept of an equivalent hysteretic damping is introduced to model random inhomogeneities.

In summary random system properties present still some conceptional but always enormous numerical difficulties in dynamic structures although the problem is under study now for more than 45 years. It appears hard to believe that there can be a theoretical break through. But the numerical techniques need to be improved. Ergodic (with respect to time) and non ergodic (with respect to spatially distributed system properties) need to be distinguished. Especially if the system is large the non-ergodic uncertainties still require the largest numerical effort.

FROM THE SAME PUBLISHER:

Li, K.S. & S-C.R.Lo (eds.) 90 5410 303 5
Probabilistic methods in geotechnical engineering – *Proceedings of the conference, Canberra, 10-12.02.1993*
1993, 25 cm, 342 pp., Hfl.185 / $105.00 / £69
Keynote addresses on recent development on geotechnical reliability and limit state design in geotechnics, and invited lectures on modelling of soil variability, simulation of random field, probabilistic of rock joints, and probabilistic design of foundations and slopes. Other papers on analytical techniques in geotechnical reliability, modelling of soil properties, and probabilistic analysis of slopes, embankments and foundations. Editors: Univ. New South Wales & Australian Defence Force Academy, Canberra.

Bui, H.D. & M.Tanaka (eds.) 90 5410 517 8
Inverse problems in engineering mechanics – *Proceedings of the 2nd international symposium, Paris, 2-4 November 1994*
1994, 25 cm, 492 pp., Hfl.185 / $110.00 / £69
Many inverse problems of great practical importance are found in engineering mechanics alone, and there is currently a dramatic increase of research activity in this area. This book contains about 65 selected papers by authors from Europe, Asia and America. The overall contents reflect the state of the art in this particular applied research area. The main topics are: Unknown shape determination; Identification of material properties; System determination; Boundary conditions and source identification; Defect identification; Mathematical and computational aspects; Experimental strategy.

Schuëller, G.I., M.Shinozuka & J.T.P.Yao (eds.) 90 5410 357 4
Structural safety & reliability – *Proceedings of the 6th international conference on structural safety and reliability, ICOSSAR '93, Innsbruck, 9-13 August 1993*
1994, 25 cm, 2348 pp., 3 vols, Hfl.375 / $210.00 / £139
326 papers on developments in structural safety & reliability that concern all types of structures from space structures to land-based facilities and ocean/offshore systems. Also included are wind engineering, seismic design, building performance, redundancy, fatigue, load modeling, optimal design & risk analysis. A valuable reference on recent developments in structural safety/reliability & probabilistic mechanics.

Teodosiu, C., J.L.Raphanel & F.Sidoroff (eds.) 90 5410 317 5
Large plastic deformations – *Fundamental aspects and applications to metal forming / Proceedings of the international seminar MECAMAT '91, Fontainebleau, France, 7-9 August 1991*
1993, 25 cm, 484 pp., Hfl.185 / $99.00 / £69
Topics covered, involve large plastic deformations of metallic materials. A view on the synergism achieved by combining microstructural characterization & understanding, mechanical modelling & experiments, numerical analysis & computation. The volume contains 96 keynote lectures & 45 contributed papers.

Andreev, G.E. 90 5410 602 6
Brittle failure of rock materials
Tests results and constitutive models
March 1995, 25 cm, c.380 pp., Hfl.195 / $115.00 / £74
Comprises different basic aspects of brittle failure for rocks. Classical & contemporary models are considered theoretically as well as failure patterns under different loading schemes. Terminology; Strength theories; Contemporary models about brittle fracture; Laborational methods for determining some mechanical properties of rocks; Mohr strength envelopes; Experimental investigation of brittle behaviour; Size effect; Concluding remarks and references.

Wang, J.G.Z.Q. & K.T.Law 90 5410 092 3
Siting in earthquake zones
1994, 25 cm, 176 pp., Hfl.135 / $75.00 / £35
Emphasises on fundamental concepts, definitions and a comprehensive method on various aspects of siting. Particularly unique in this book is a detailed checklist to guide the readers to conduct a proper siting process to assess the seismic hazards of a given site. The required site investigation techniques are described in detail. *Contents:* Fundamentals; Major program & methods of siting; Earthquake ground motion; Seismic hazard analysis for a site; Evaluation of seismic parameters; Seismic effect fault & faulting; Seismic liquefaction of soil; Slope stability; Ground waving & its damaging effect.

Xie, Heping (M.A.Kwasniewski, Editor-in-Chief) 90 5410 133 4
Fractals in rock mechanics (Geomechanics Research Series, 1)
1993, 25 cm, 464 pp., Hfl.150 / $85.00 / £55
Important developments in the progress of the theory of rock mechanics during recent years are based on fractals and damage mechanics. The book is concerned with these developments, as related to fractal descriptions of fragmentations, damage, and fracture in rocks, rock bursts, joint roughness, rock porosity and permeability, rock grain growth, rock and soil particles, shear slips, fluid flow through jointed rocks, faults, earthquake clustering, etc. A simple account of the basic concepts, methods of fractal geometry & their applications to rock mechanics, geology & seismology. Discussion of damage mechanics of rocks & its application to mining engineering. Author: China Univ. of Mining & Technology, Xuzhou, China.

Saxena, K.R. 90 5410 278 0
Geotechnical engineering: *Emerging trends in design and practice*
1994, 25 cm, 410 pp., Hfl.105 / $60.00 / £39 (No rights India)
New approaches & state-of-the-art reports on sampling disturbance & application of numerical models, study of swelling characteristics of deep residual clays, cemented marine carbonate soils, constitutive models & geotechnical applications, control of uncertainty, determination of design parameters, embankment dam & earthquakes, machine foundations, design & construction of tailings dams, geosynthetics in embankment dams & as material for soil reinforcement.

Lancellotta, R. 90 5410 178 4
Geotechnical engineering
April 1995, 25 cm, c.400 pp., Hfl.190 / $95.00 / £70
(Student edn., 90 5410 179 2, Hfl.115 / $60.00 / £43)
This book is about the mechanics of soils and structures interacting with soils, based on the material collected at the Technical University of Turin over the past two decades. *Contents:* Nature and composition of soils; The principle of effective stress and the state variables; Fundamentals of continuum mechanics; The porous medium: steady flow; The porous medium: transient flow; Stress-strain and strength characteristics; In-situ investigations; The collapse of soil structures; Performance and serviceability of structures; References; Index. Author: Technical University of Turin, Italy.

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