



Afdelingen for Bærende Konstruktioner  
Department of Structural Engineering

Danmarks Tekniske Universitet • Technical University of Denmark

Resuméoversigt 1994

Summaries of Papers 1994

**AFDELINGEN FOR BÆRENDE KONSTRUKTIONER**

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**RESUMÉOVERSIGT 1994**

**\*Summaries of Papers 1994**

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**Resuméoversigt 1994 - Summaries of Papers 1994**

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Tryk:

Afdelingen for Bærende Konstruktioner

Danmarks Tekniske Universitet

Lyngby

ISBN 87-7740-161-1

ISSN 0909-587X

Bogbinder:

H. Meyer, Bygning 101, DTU

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The series R (Report ISSN 0108-0768), in which the research reports are being published may be obtained in subscription. The subscription price outside Denmark, covering publications in the period 1st July 1995 to 30th June 1996, is D.kr. 130,-. Payment should accompany orders of subscription.

A publication exchange agreement may be made with institutions working with structural research problems. Please apply for further information.

AGERSKOV, H., and J.B. IBSØ: \*An investigation on Fatigue in Repair-Welded Tubular Joints in Offshore Structures. (En undersøgelse af udmattelse i reparationssvejste rørknudesamlinger i offshorekonstruktioner). Proc. of the International Institute of Welding, Annual Assembly, Beijing, September, 1994, IIW Doc. XIII-1525-94, 32 pp. (Reprints available).

\*In the present investigation, the fatigue life of repair-welded tubular joints in offshore structures is studied. This investigation is a part of a series of research projects on fatigue in offshore structures, carried out at the Technical University of Denmark. The primary purpose of these projects is to study the fatigue life of tubular joints under various types of stochastic loading that are realistic in relation to offshore structures.

Two test series on full-scale tubular joints have been carried out. One series was on joints in the as-welded condition, and the other series was on test specimens, in which the fatigue cracks that developed during the first series of tests, had been repair-welded. This welding was carried out according to procedures used presently in the North Sea in repair of fatigue cracks in tubular joints. It was expected beforehand that the repair-welded joints would have fatigue lives that were shorter than those of the original joints. However, the tests carried out showed that the repair-welded joints had fatigue lives of 1.9-5.0 times the life of the original joints. These observations are discussed in the paper, and the main reason for these results is explained.

AGERSKOV, H., R.I. PETERSEN and L. LOPEZ MARTINEZ: \*Fatigue in High-Strength Steel Offshore Tubular Joints. (Udmattelse i rørknudesamlinger i offshorekonstruktioner i højstyrkestål). Proc. of the 6th International Symposium on Tubular Structures, Melbourne, December, 1994, pp. 527-534. (Reprints available).

\*The fatigue life of tubular joints in offshore steel structures is studied. Two test series on full-scale tubular joints have been carried through. One series was on joints in conventional offshore structural steel, and the other series was on joints in high-strength steel with a yield

stress of 820-830 MPa and with high weldability and toughness properties. The test specimens of both series had the same geometry. The present paper concentrates on the results obtained in the investigation on the high-strength steel tubular joints.

The test specimens were fabricated from  $\varnothing$  324-610 mm tubes, and the joints were loaded in in-plane bending. Both fatigue tests under constant amplitude loading and tests with a stochastic loading that is realistic in relation to offshore structures, are included in the investigation.

A comparison between constant amplitude and variable amplitude fatigue test results showed shorter fatigue lives in variable amplitude loading than should be expected from the linear fatigue damage accumulation formula. Furthermore, the fatigue tests on high-strength steel tubular joints showed slightly longer fatigue lives than those obtained in corresponding tests on joints in conventional offshore structural steel.

ARNBJERG-NIELSEN, TORBEN, se DITLEVSEN, OVE og TORBEN ARNBJERG-NIELSEN

ASKEGAARD, VAGN: \*Experimental Mechanics and Stored Particulate Solids. (Eksperimentel Mekanik og silo opbevarede materialer). 10th Intern. Conf. on Experimental Mechanics. "Invited lectures" udgivet af APAET-LNEC Lissabon, 18-22 Juli 1994, 11 sider. (Reprints available).

\*Theoretical predictions of the stress- and flow state of particulate materials contained in silos are still inadequate due to the very complex material properties of the particulate media and the complex loading the materials undergo.

Experiments, therefore, play an important role in silo research partly by improving the assumptions on which the theories are built and partly by checking the calculated stress- and flow states.

This demands a continued development of experimental methods and of their calibration such that experimental values can be presented with a known accuracy. Examples of important experimental observations and error sources are mentioned in the paper.

CHRISTENSEN, CLAUS, se DITLEVSEN, OVE, CLAUS CHRISTENSEN og SØREN RANDRUP-THOMSEN

CHRISTOFFERSEN, JENS, se JAGD, LARS, JENS CHRISTOFFERSEN og M.P. NIELSEN

DAHL, KAARE, K.B.: \*Construction Joints in Normal and High Strength Concrete. (Støbeskel i normal og højstyrkebeton). Afdelingen for Bærende Konstruktioner. Serie R, nr. 314, 1994. 23 s. + appendiks 6 s. Gratis.

\*This report describes the test rig used, and the results obtained, in a large investigation concerning the shear strength of construction joints in concrete. The work is centred on concretes in the strength range 20 to 100 MPa.

For this range of concrete strengths, smooth and rough construction joints have been studied.

It was found that the relative shear strength of a construction joint is depending on the strength of the concrete, and that the relative shear strength is decreasing for increasing concrete strength.

It was also found that the Danish national code DS 411 generally predicts too low shear strength of construction joints. Based partly on the results obtained in this investigation, and partly on other test results, a revision of the code is proposed.

The investigation also points at the need for reevaluation of the classification rules for construction joints. This because high-pressure water or water/sand blasting of the construction does not seem to ensure that a construction joint can be classified as a rough joint, although the roughness criteria as specified in the code is respected.



Denne rapport beskriver forsøgsopstillingen, samt de opnåede resultater, i et stort forsøgsprogram omhandlende forskydningsstyrken af støbeskel i beton. De undersøgte betoner varierede i styrke fra 20 til 100 MPa.

For denne variation af betonstyrken er forskydningsstyrken for både glatte og ru støbeskel undersøgt.

Det blev fundet, at den relative forskydningsstyrke i et støbeskel er afhængig af betonstyrken, og at den relative styrke daler for stigende betonstyrke.

Det blev ligeledes fundet, at DS 411 generelt tillader for lave forskydningsstyrker i støbeskel. Baseret dels på resultaterne opnået i denne undersøgelse, og dels på andre forsøg, er en revidering af DS 411 foreslået.

Undersøgelsen peger også på behovet for en reevaluering af klassifikationsreglerne for støbeskel. Dette på baggrund af, at undersøgelsen bl.a. viste, at højtryksspuling af et støbeskel, enten alene med vand, eller med en blanding af vand og sand, ikke er nok til at sikre et ru støbeskel. Dette desuagtet, at ruhedskriteriet, som specificeret i DS 411, er overholdt.

DAMKILDE, L., O. HØYER and S. KRENK: \*A Direct Linear Programming Solver in C for Structural Applications. Computers & Structures, Vol. 52, No. 3, 1994, pp. 511-528. (Reprints available).

\*An optimization problem can be characterized by an object-function, which is maximized, and restrictions, which limit the variation of the variables. A subclass of optimization is Linear Programming (LP), where both the object-function and the restrictions are linear functions of the variables. The traditional solution methods for LP problems are based on the simplex method, and it is customary to allow only non-negative variables. Compared to other optimization routines the LP solvers are more robust and the optimum is reached in a finite number of steps and is not sensitive to the starting point.

For structural applications many optimization problems can be linearized and solved by LP routines. However, the structural variables are not always non-negative, and this requires a reformulation, where a variable  $x$  is substituted by the difference of two non-negative

variables,  $x^+$  and  $x^-$ . The transformation causes a doubling of the number of variables, and in a computer implementation the memory allocation doubles and for a typical problem the execution time at least doubles.

This paper describes a LP solver written in C, which can handle a combination of non-negative variables and unlimited variables. The LP solver also allows restart, and this may reduce the computational costs if the solution to a similar LP problem is known *a priori*. The algorithm is based on the simplex method, and differs only in the logical choices. Application of the new LP solver will at the same time give both a more direct problem formulation and a more efficient program.

DAMKILDE, L. and S. KRENK: \*LimitS - A System for Limit State Calculation of Collapse Load or Optimal Material Layout. Advances in Structural Optimizations (eds.: B.H.V. Topping and M. Papadrakakis), 1994, CIVIL-COMP Ltd., Edinburgh, Scotland, 1994, pp. 171-178. (Reprints available).

\*A system LimitS for limit state analysis and material optimization has been developed and implemented in a PC environment. The program is based on a general Finite Element format with stress based elements. The solution method is based on the lower-bound theorem, where an optimal stress distribution or an optimal material layout is determined. Through linearization of the yield criteria the optimization problem is stated as a Linear Programming problem. The optimal lower-bound solution is shown to be an upper-bound solution for the discretized problem, and thereby both the statics and kinematics of the collapse mode is determined via the dual variables of the LP-problem.

In LimitS the following element types are implemented: 2D and 3D beam elements, truss elements, triangular slab elements, and shear and stringer elements for plates with inplane loading. Examples of all 3 problem types are given including both limit state analysis and material optimization.

DAMKILDE, LARS and S. KRENK: \*Single bolt connections in thin-walled lattice girders.

In Proceedings of "Workshop on Semi-Rigid Behaviour of Civil Engineering Structures", Prague, 1994, pp. 1-10. (Reprints available).

\*Cold-formed steel-profiles with C- or hat-shapes have proven to be very economic in design of lattice girders with spans around 20-30 m.

The loading capacity of the lattice girder is controlled by stability either in a single member or as a global collapse mode. The stability collapse involves combined torsion and bending in the members due to the relatively low torsional stiffness of the individual beams, and the analysis must be based on Vlasov's theory for thin-walled beams.

The flexibility of the connections has great influence on the stability behavior, and a model for a single bolt connection is proposed. The theoretical model is compared with experimental results for both full-scale lattice girders and tests of single elements. The calculations show good agreement between theory and experiment, and also show the importance of the connection model.

DAMKILDE, LARS, JØRGEN FLEMMING OLSEN and PETER NOE POULSEN:

\*A Program for Limit State Analysis of Plane, Reinforced Concrete Plates by the Stringer Method. Bygningsstatistiske Meddelelser, Vol. 65, No. 1, 1994, pp. 1-26. (Reprints available).

\*A numerical method for the limit state analysis of plane, reinforced concrete plates is developed. The external load is carried by a combination of vertical and horizontal stringers, which are either in tension or compression, and rectangular elements, which only take pure shear.

The algorithm is based on the lower-bound theorem, and the implementation is based on the finite element concept, which allows to analyse fully general configurations. The yield criteria are linearized, and the approach allows both a load optimization for a given design and a design optimization for given load cases. Practical design constraints are implemented.

The method has been implemented in a computer program written in C, and examples on both load and material optimization are shown. The program can easily run on a standard PC, and the execution time for practical design problems is modest.

Artiklen beskriver en numerisk metode til brudstadieregning af plane, armerede betonskiver regnet efter stringermetoden. Den ydre last bæres af et system bestående af lodrette og vandrette tryk- eller trækstringere og rektangulære felter i ren forskydning.

Algoritmen er baseret på nedre-værdi sætningen, og implementeringen er baseret på en elementmetodeformulering, der tillader vilkårlige udformninger. Brudkriteriet er lineariseret, og fremgangsmåden kan bruges til både lastoptimering for en given konstruktionsudformning og materialeoptimering for givne belastningskombinationer. Endvidere er praktiske konstruktionskrav implementeret.

Metoden er implementeret i et computerprogram skrevet i C, og der vises eksempler på både last- og materialeoptimering. Programmet kan afvikles på en PC, og køretiden er for praktiske eksempler beskedent.

DAMKILDE, L., se også JÖNSSON, J., S. KRENK og L. DAMKILDE

DAMKILDE, L., se også KRENK, S., L. DAMKILDE og O. HØYER

DITLEVSEN, OVE and TORBEN ARNBJERG-NIELSEN: \*Model-Correction-Factor Method in Structural Reliability. Journal of Engineering Mechanics, Vol. 120, No. 1, January, 1994, paper No. 4780, p. 1-10. (Reprints available).

\*Under general conditions reliability analyses of elaborate structural models can be replaced by much simpler equivalent reliability analyses of corresponding idealized structural models such as those based on rigid-plastic theory. The equivalence is in the sense of being with respect to probability of failure and is obtained by applying a random factor correction of the

strength variables of the simple model. This model-correction factor is called the effectivity factor, and it is approximated to the zeroth order by a constant or to the first order by an inhomogeneous linear function of all the basic variables in the realistic model. The coefficients of this function are calculated from the elaborate model (e.g., by finite element calculations) with values of the input variables chosen on the basis of a first-order reliability analysis of the simple model (FORM). The model-correction-factor method is a special type of response-surface method based on mechanical principles. It is illustrated quantitatively on a yield hinge frame model with strain softening mutual rotation-moment behavior in the hinges upon the onset of yielding.

DITLEVSEN, O. and A. VROUWENVELDER: \*"Objective" low informative priors for Bayesian inference from totally censored Gaussian data. Structural Safety, Vol. 16, 1994, pp. 175-188. (Reprints available).

\*Consider structural elements with random strength that after a suitable transformation has normal distribution with unknown mean  $\mu$  and known or unknown standard deviation  $\sigma$ . By proof testing of  $n$  of these structural elements to a given load level it is observed that none of the elements fail. Given solely this test information the problem is that in order to state anything about either the value of  $\mu$  when  $\sigma$  is known or about the values of  $\mu$  and  $\sigma$  when both parameters are unknown, it is necessary to introduce some more information in the form of a suitable prior distribution of the parameters, that is, to use a Bayesian procedure with an informative prior. The paper considers the problem of defining such a prior in an axiomatic ("objective") way without extending the information represented by the test results by more than very little extra information based on common physical sense.

The solution suggested in the paper implies that the posterior distribution of the mean shifts towards larger values when the sample size  $n$  increases. However, convergence to a specific value is not obtained as long as no failures are observed among the tests. Moreover, it turns out that the posterior distribution of the standard deviation is invariant to the sample size  $n$ ,

that is, no updating of the standard deviation is obtained as long as there are no failures among the tests.

DITLEVSEN, OVE: \*Traffic Loads on Large Bridges Modeled as White-Noise Fields. Journal of Engineering Mechanics, Vol. 120, No. 4, April, 1994, pp. 681-694. (Reprints available).

\*A load effect from the traffic load on a large bridge with a large interval of slowly varying nonzero influence on the load effect can be modeled as a Gaussian random process. The mean value function and the covariance function that completely determine the process can be obtained by modeling the traffic load along each lane as a translating white-noise field. On the basis of a realistic traffic theoretical modeling of the instantaneous random positions of single vehicles as represented by their random weights, the paper derives formulas for the mean and intensity of the white-noise traffic-load field in terms of traffic parameters and vehicle weight mean and variance. The formulas cover the entire range of traffic from free Poissonian traffic to congested traffic with the full stop queue as a limit case. The standard level crossing rate approximation method, used for the distribution of the maximal load effect over a given period of time due to moving traffic of any type is taken as an example of an application of the white-noise traffic-load model. In a companion paper, Ditlevsen and Madsen (in press, 1994) used the model to obtain the distribution of the maximal load effect during a given period of time due to the formation of standing queues on the bridge.

DITLEVSEN, OVE, CLAUS CHRISTENSEN and SØREN RANDRUP-THOMSEN:

\*Reliability of Silo Ring under Lognormal Stochastic Pressure Using Stochastic Interpolation. Proceedings of IUTAM Symposium: Probabilistic Structural Mechanics: Advances in Structural Reliability Methods, San Antonio, Texas, 1993. (eds.: P.D. Spanos, Y.-T. Wuleda). Springer Verlag, pp. 134-162. (Reprints available).

\*A Gaussian stochastic silo load model for circular cells has been formulated and used for reliability analysis in two previous papers. In order to avoid negative stresses orthogonal to the wall the possibility of modeling the wall stresses by a non-Gaussian field such as the lognormal field is considered herein. Several fundamental problems by such modeling are revealed. These problems concern the mandatory nonnegativity properties of the covariance structure under certain equilibrium restrictions. However, the investigations also show that the distribution assumption has a substantial influence on the reliability results in spite of the intuitive (but unjustified) reliance on the validity of the central limit theorem for integrals of random fields.

For the practical reliability analysis of the silo wall it is necessary to make a discretization of the random field into another random field defined in terms of a finite, but not too large, set of correlated random variables. It turns out to be essential for the discretization replacement to base it on stochastic interpolation in a particular form. In order to gain insight into the problem the mechanical part of it is kept simple by solely considering the analysis for a ring imagined to be cut out by two consecutive horizontal planes an infinitesimal distance apart at a place far away from regions of the silo with end effects on the internal forces.

The reliability analysis is made with respect to the initial formation of a yield hinge among a finite set of cross-sections. Moreover, a reliability analysis with respect to the development of a collapse mechanism in the ring is considered. The influence of the correlation length (scale of fluctuation) on the reliability is illustrated for both types of limit states. All reliability calculations are made by the standard methods FORM, SORM using the DNV (Det Norske Veritas) program PROBAN.

DITLEVSEN, OVE: \*Reexamination of Convex Polyhedron Outcrossing Problem. Journal of Engineering Mechanics, Vol. 120, No. 3, March, 1994, pp. 654-660. (Reprints available).

\*Structural series-system reliability analyses formulated solely by use of a finite number of random variables can often be done with sufficient accuracy in terms of first- or second-order upper and lower bounds on the system failure probability. The bounds are of the first order if they are defined solely by the single-element-failure probabilities, and of the second order if they also include the probabilities of the intersections of the failure events of any two single elements. A reexamination of the proof of the most well-known pairs of second-order bounds shows that almost the same reasoning can be used to obtain similar formulas for upper and lower bounds on the outcrossing rate of a general vector process out of the safe set of a series system. For polyhedral safe sets and smooth Gaussian vector processes, the needed outcrossing formulas are given explicitly in a form that is well suited to be put on computer.

DITLEVSEN, OVE and HENRIK O. MADSEN: \*Stochastic Vehicle-Queue-Load Model for Large Bridges. Journal of Engineering Mechanics, Vol. 120, No. 9, September, 1994, Paper No. 6280, pp. 1829-1847. (Reprints available).

\*For long-span bridges, the traffic load can be modeled as white-noise-load fields along the lanes. The mean and the intensity of the white-noise field depend on the traffic situation. Theoretical expressions in terms of the traffic parameters are available for these white-noise-field characteristics covering the entire range from free Poissonian traffic to dense congested traffic that in the limit of zero vehicle velocity becomes a standing queue of vehicles. This paper presents a stochastic model for the load-effect pulse process caused by the formation of queues of stopped vehicles. The key assumptions leading to the model are the following: (1) The probabilistic structure of the succession of cars and trucks in the queue is generated on the basis of the free Poissonian traffic situation; (2) the occurrences of standing queues are Poissonian and sufficiently rare to justify the neglect of the effect of within-lane overlap; (3)



the queue durations and lengths are exponentially distributed; and (4) the central-limit theorem is effective implying asymptotic Gaussianity of the load effect from any given lane interval fully covered by a stochastically homogeneous traffic load. Assumption 3 is not in conflict with actual observations on a German freeway, whereas assumption 4 has been justified for specific examples by computer simulations using different truck-weight distributions of given mean and standard deviation. Finally, it is shown by use of the model that the effect of queue overlap in the case of two-way traffic on the bridge can be decisive for the reliability analysis of the considered component of the bridge.

DITLEVSEN, OVE: \*Qualified Envelope Excursions out of an Interval for Stationary Narrow-Band Gaussian Processes. Journal of Sound and Vibration, 1994, Vol. 173, No. 3, pp. 309-327. (Reprints available).

\*The study of the plastic displacements of the response of the bilinear elasto-plastic oscillator (EPO) excited by a stationary wide-band Gaussian process motivates the problem of determining the long run fractions of differently characterized qualified envelope excursions of a stationary Gaussian process above given thresholds. An extension of a previously published Slepian model approach gives answers that fit reasonably well with simulation results. A probabilistic argument provides an approximate bounding of the plastic displacement process of the bilinear EPO.

DITLEVSEN, OVE: \*Measuring uncertainty correction by pairing. Proceedings of ICOSSAR'93 - The 6th International Conference on Structural Safety and Reliability, Innsbruck, Austria, 1993. Structural Safety & Reliability, (eds.: Schuëller, Shinozuka & Yao), Balkema, Rotterdam, 1994, pp. 1977-1983. (Reprints available).

\*Under certain circumstances a pairing of measurements from two independent and possibly inaccurate measuring methods reveals information about the population of measuring objects

as well as about the two measuring error populations. This pairing method in combination with stochastic interpolation principles is the basis for a method of getting information about the uncertainty related to measurements of spatial variations of soil properties and of separating the uncertainty population and the property population from each other. The method is developed for the following particular application. Elasto-plastic continuum mechanics predicts that there is almost proportionality between the undrained shear strength  $c_v$  as measured by the vane test and the cone tip resistance  $q_c$ , both imagined to be measured at the same point of an ideal saturated clay. Taking this as a "law", observed deviations of the measured pairs  $(c_v, q_c)$  from being situated on the same straight line through the origin in the  $(c_v, q_c)$  coordinate system must be attributed to measuring uncertainty. In fact, large deviations are observed in practice because in the pair  $(c_v, q_c)$  assigned to a given point the value of  $q_c$ , say, must be obtained by interpolation between values of  $q_c$  measured at other points of the soil body. Acceptance of the proportionality law makes it possible by the pairing method to estimate the proportionality constant as well as the measuring uncertainty of both  $c_v$  and  $q_c$  in terms of probability distributions. This leads to the transformation of the random field of "measured"  $q_c$  values into the random field of "true" undrained shear strength values. The developed technique has been successfully applied to an extensive set of filtered CPT (cone penetration test) cone tip resistance measurements made in the Storebælt clay till in Denmark. This investigation has served the preparation of the anchor block design for the suspension bridge presently under construction.

DITLEVSEN, OVE: \*Decision Making Facing Risk Aversion. Proceedings of a Symposium on Risk Analysis. University of Michigan, Ann Arbor, Michigan, (ed.: Andrzej S. Nowak), pp. 49-54. (Reprints available).

\*It is claimed in this revised extract from Ditlevsen (1991) that the problem of risk aversion can be dealt with on a rational basis within the framework of the decision theory of Von Neumann and Morgenstern (1943). Risk aversion is here defined as the attitude that a large loss (e.g. of human lives) by one single accident is evaluated as considerably worse than the

accumulation to the same loss by many separated accidents distributed over some time. Examples illustrate how the ordinary decision theory allows rational modeling of risk aversion related to specific engineering projects.

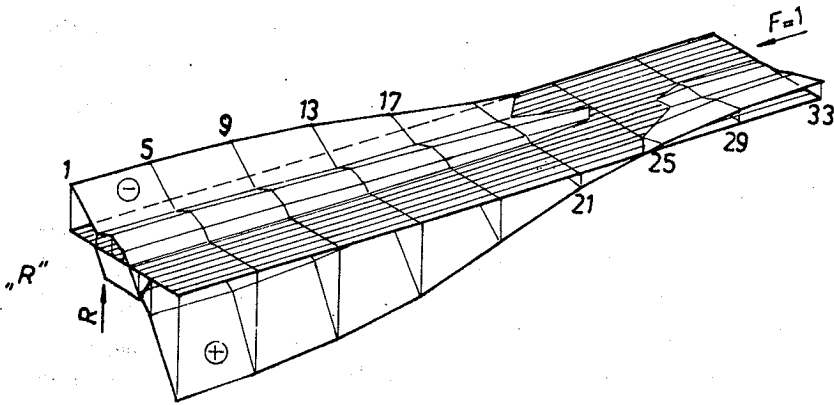
DITLEVSEN, OVE: \*Distribution arbitrariness in structural reliability. Proceedings of ICOSSAR'93 - The 6th International Conference on Structural Safety and Reliability, Innsbruck, Austria, 1993. Structural Safety & Reliability, (eds.: Schuëller, Shinozuka & Yao), Balkema, Rotterdam, pp. 1241-1247. (Reprints available).

\*The author points at the urgent need for code standardizations of distribution types for practical design applications of structural reliability methods. In support of the author's opinion that distribution type standardizations are necessary in order to avoid reliability comparisons on the basis of incommensurable reliability measures, the paper demonstrates the fundamental difficulty of choosing the probability distributions for example for annual extreme loads such as wind and snow loads for which only limited data series are available. Moreover, it is argued that even if several distribution types may pass a statistical test not all of these are reasonable candidates for standardization. The class of standardized distributions in a code of practice for reliability analysis should be looked upon as an internally harmonized entity chosen on the basis of consequence calculations applied to the class of structures for which the code is intended. Otherwise even the imposed ordering with respect to reliability becomes dubious.

DULEVSKI, ENCHO M.: \*Global Structural Analysis of Steel Box Girder Bridges for Various Loads. (Global statistisk analyse af stålbroer med kassedragere for forskellige laster). Afdelingen for Bærende Konstruktioner. Serie R, nr. 309, 1994. 27 s. Gratis.

\*A basic information concerning algorithm and computer programs for steel box girder bridge analysis subjected to various loads is given. FEM is applied. Several modifications of a basic

program are developed to include wind loading, longitudinal forces action (braking and acceleration forces), temperature difference action, support displacements, besides the vertical loading. For each of these actions some interesting results, obtained for a steel continuous box girder, are presented.



Influensflade for reaktionen R .

\*Influence surface for the support reaction R .

Ref.: DULEVSKI, ENCHO M.: Global Structural Analysis of Steel Box Girder Bridges for Various Loads. (s. 18).

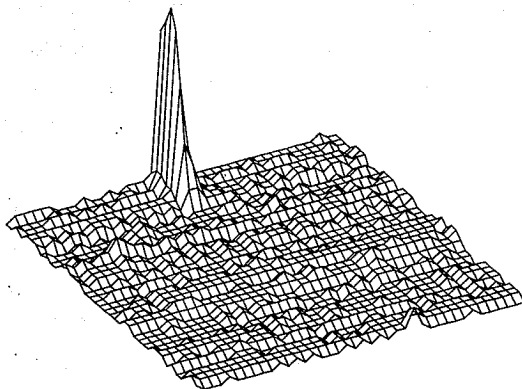
GLAVIND, M. and H. STANG: \*Review of Application of Fiber Concrete and Fiber Cement in Denmark. (Anvendelse af Fiberarmeret Beton og Fiberarmeret Cement i Danmark). Brittle Matrix Composites 4, (eds.: A.M. Brandt and I.H. Marshal). Woodhead Publishing Limited, Warsaw, 1994, pp. 51-60. (Reprints available).

\*A review is presented of typical applications of fiber reinforced cementitious composites in Denmark highlighting the purpose of using fiber reinforcement, design basis, processing technology and condition of the structures. A state of the art of research in fiber reinforced cementitious composites - particularly in Denmark - is given and compared with present applications. Finally, research needs identified from the application point of view are identified and discussed.

I artiklen gives en oversigt over typiske anvendelser for fiberarmerede cementbaserede kompositmaterialer i Danmark, idet formål med anvendelse af fiberarmering, designgrundlag, fremstillingsmetoder og konstruktionens tilstand beskrives. State of the Art inden for forskning i fiberarmerede cementbaserede kompositter - specielt i Danmark - beskrives og sammenlignes med anvendelsen af disse materialer i praksis. Til slut identificeres og diskuteres forskningsbehov ud fra et anvendelsessynspunkt.

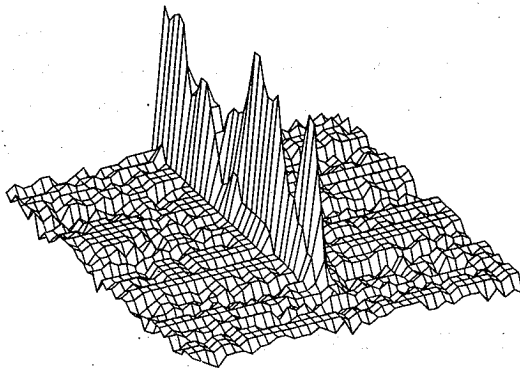
HANSEN, THOMAS CORNELIUS: \*Fatigue and Crack Propagation. (Udmattelse og Revnevækst). Afdelingen for Bærende Konstruktioner. Serie R, nr. 316, 1994. 99 s. + appendix 33 s. Gratis. /Ph.D./.

\*The main purpose of this paper is to test a new theory of crack propagation by comparing its results with test results. The advantage of the new theory is that crack propagation may be predicted on the basis of knowledge of well-known material parameters, contrary to the empirical formulas, the parameters of which must be determined by time consuming fatigue tests.



Referencebillede af revnespidsen.

\*Reference image showing the crack tip.



Billede af revnespidsen efter revnevækst.

\*Image showing crack tip after crack growth.

Ref.: HANSEN, THOMAS CORNELIUS: Fatigue and Crack Propagation. (s. 20).

To test the theory three types of tests have been performed. Firstly, a simple tension test to determine the yield strength and the true fracture strength and the modulus of elasticity (chapter 3). Secondly, a standard  $K_{IC}$  test to determine the critical stress intensity factor  $K_{IC}$ , and to show the dependency of  $K_{IC}$  upon the stress intensity factor  $K_I$  (chapter 4). Finally, fatigue tests were performed (chapter 5). All the tests were done on three different materials. The chosen materials are two high strength aluminiums (Al2024 and Al7075) and one high strength steel (Hardox 400).

The theory is based on an energy balance criterion. The results from the three tests are analysed and the crack propagation behavior is calculated on the basis of the test results.

Hovedformålet med denne rapport er at eftervise en nyudviklet revnevækstteori ved at sammenholde dens resultater med forsøg. Fordelen ved den nye teori er, at den er baseret på velkendte materialeparametre, ikke på empiriske konstanter udledt ved tidskrævende udmattelsesforsøg.

For at eftervise teorien er der udført tre typer af forsøg. Først et simpelt trækforsøg med det formål at bestemme flydespænding, den sande brudspænding og elasticitetskoefficienten, kapitel 3. Dernæst er der udført et standard  $K_{IC}$ -forsøg med det formål at bestemme den kritiske spændingsintensitetsfaktor  $K_{IC}$ , og vise dens afhængighed af spændingsintensitetsfaktoren  $K_I$ , kapitel 4. Til sidst udførtes en serie udmattelsesforsøg, kapitel 5. Alle forsøg blev udført på tre forskellige materialer. De valgte materialer er to højstyrke aluminium (Al2024 og Al7075) og et højstyrke stål (Hardox 400). Teorien er baseret på en energiligning. Resultaterne fra de tre forsøg er analyseret, og revnevækstforløbet er beregnet på basis af forsøgsresultaterne.

HØYER, O., se DAMKILDE, L., O. HØYER og S. KRENK

HØYER, O., se KRENK, S., L. DAMKILDE og S. HØYER

IBSØ, J.B., se AGERSKOV, H. og J.B. IBSØ

JAGD, LARS, JENS CHRISTOFFERSEN and M.P. NIELSEN: \*The HOTCH-POTCH Disk Element - Finite Element for Analysis of Reinforced Concrete Disks. (HOTCH-POTCH skiveelementet. Finite element til beregning af armerede betonskiver). Afdelingen for Bærende Konstruktioner. Serie R, nr. 317, 1994. 33 s. Gratis.

\*The report describes a new disk element, used for finite element analysis, which is based on a simple, mechanical model, that causes normal stresses to be concentrated in stringers along the element edges and shear to be transferred by a constant in-plane shear stress field.

The element has a transparent behavior very similar to the stringer method, and the constant shear stress within each element makes it well-suited for analyses and design of reinforced concrete disks.

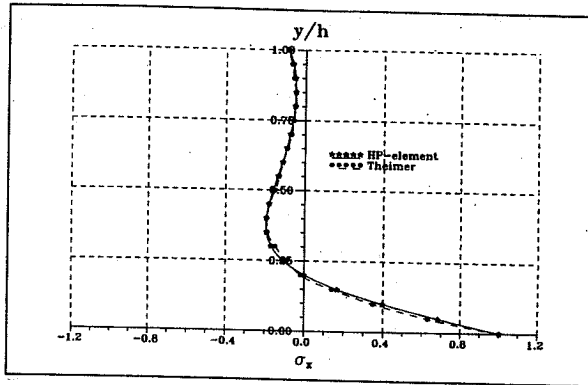
The element has been implemented in a finite element programme. Input and output is of a form that can easily be converted to typical reinforcement detailing.

A number of test problems have been analyzed and the results compared with various theoretical results as well as with another FEM programme. All the problems yield very accurate results, the computational efforts taken into account.

JAGD, LARS, JENS CHRISTOFFERSEN and M.P. NIELSEN: \*The HOTCH-POTCH Shell Element - Finite Element for Analysis of Reinforced Concrete Shells. (HOTCH-POTCH skalelement - Finite element til beregning af armerede betonskaller). Afdelingen for Bærende Konstruktioner. Serie R, nr. 318, 1994. 56 s. Gratis.

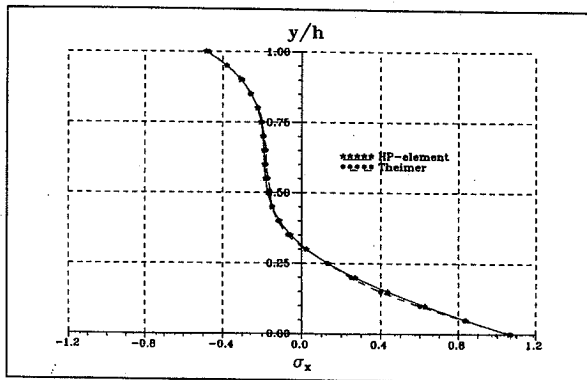
\*The report describes a new shell element, used for finite element analysis, which is based on simple, mechanical models that cause normal stresses to be concentrated in stringers along the element edges and shear to be transferred by a constant in-plane shear stress field. The torsional and flexural rigidities are separated, making independent specifications of these possible.





$\sigma_x$  i midtersnittet,  $h/l = 1$ .

\* $\sigma_x$  in the mid span section,  $h/l = 1$ .



$\sigma_x$  i midtersnittet,  $h/l = 2/3$ .

\* $\sigma_x$  in the mid span section,  $h/l = 2/3$ .

Ref.: JAGD, LARS, JENS CHRISTOFFERSEN og M.P. NIELSEN: The HOTCH-POTCH Disk Element. (s. 23).

The element is neither a compatible nor an equilibrium element but is an equilibrium element for a transformed shell consisting of a disk with in-plane rigidity, a plate with no flexural rigidity and a grid system with no torsional rigidity. The element is, therefore, called the 'Hotch-Potch' shell element or simply the HP shell element.

The element has a behavior very similar to the stringer method and is ideally suited for analyses of e.g. cylindrical shells with stiffeners or reinforced concrete shells.

In the report the geometric stiffness matrix for the element is also developed. This makes it possible to use the element for large deformation analyses.

The element has been implemented in a finite element programme and a number of test problems have been analysed. Compared with theoretical solutions, all the problems yield very accurate results, the computational efforts taken into account.

JENSEN, J.-E.B., H. STANG, B. KRINGSHOLM and O.H. SØRENSEN: \*Biomechanical Quality of Trabecular Bone. A New Method. (Trabekulært Knoglevævs Biomekaniske Egenskaber. En ny Metode). International Conference on Progress in Bone and Mineral Research, Programme and Abstracts, October 14-16, 1994. Vienna, Austria, abstract 59, p. 24. (Reprints available).

\*A new test method for the determination of the true stress-strain curve on bone biopsies is described. The effect of measuring technique, humidity and specimen size is discussed. It is concluded that the biomechanical qualities of a bone biopsy can be very precisely evaluated and artifact from the contact zone between bone and test equipment are minimized.

En ny testmetode til bestemmelse af den sande spændings-tøjningskurve for knoglebiopsier beskrives. Betydningen af målemetode, fugtighed og prøvelegemestørrelse bliver diskuteret. Det konkluderes, at de biomekaniske egenskaber af en knoglebiopsi kan bestemmes meget præcist, og at fejlkilder hidrørende fra kontaktzonen mellem knogle og prøvningsudstyr kan elimineres.

JUN, Z., se STANG, H. og Z. JUN

JÖNSSON, J., S. KRENK and L. DAMKILDE: \*Semi-Loof Element for Plate Instability. Communications in Numerical Methods in Engineering, Vol. 10, 1994, pp. 11-19. (Reprints available).

\*In the formulation of the Semi-Loof element the rotation of the tangent plane is derived from the interpolation of the transverse displacement, while the rotation of the normal is interpolated separately by another set of shape functions. The geometric stiffness matrix can be formulated by use of either of the two rotation representations. It is demonstrated that the use of the tangent plane representation in the geometric stiffness matrix is far superior to the common form at present.

KARLSHØJ, JAN: Principper og metoder for opstilling af datamodeller til byggetekniske anvendelser. (\*Principles for product models in building design. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 315, 1994. 294 s. Gratis. /Ph.D./

Rapporten omhandler opstilling og udnyttelse af produktmodeller til den ingeniørmæssige del af bygningsprojekteringen. I rapporten beskrives en række danske og udenlandske produktmodeller samt egne forslag til, hvordan informationsteknologien kan udnyttes i byggesektoren.

Systemanalysen, der bruges som et hjælpemiddel til opbygning af produktmodeller, illustreres gennem anvendelse af forskellige analysemetoder. Forskellige metoder til dannelse af informations- og funktionsmodeller sammenlignes indbyrdes og med objektorienterede analysemetoder.

En række danske og udenlandske bygningsproduktmodeller vurderes, og det konkluderes, at flere af de hidtidige modeller tager udgangspunkt i en økonomisk, entreprenør/mængdemæssig synsvinkel. Eksisterende og kommende udvekslings- og klassifikationsstandarder beskrives, herunder den kommende internationale standard for udveksling af produktmodel data, STEP.

De tilgængelige databasetyper - hierarkiske, netværks-, relations- og objektorienterede databaser - beskrives, og brugen af standarddatabaser til lagring af teknisk orienterede og geometriske data inden for ingeniørdisciplinerne vurderes.

Brugen af informationsteknologien har øget behovet for et automatisk data management system, som registrerer dokumenters placering, ansvar for data, versioner af data m.v. Nødvendigheden af et fælles styrende data management system eksemplificeres.

KONstruktions Informations Modellen KONIM, der er en bygningsproduktmodel, opstilles og vurderes. KONIM er baseret på et referenceprincip, hvor det kun er en mindre del af bygværkets informationer, der lagres i produktmodellens kerne, mens der skabes referencer til alle øvrige informationer.

Det konkluderes, at brugen af systemanalyse, produktmodeller og databasebaseret programmer får afgørende betydning for bestræbelserne på at opnå en mere integreret informationsbehandling i fremtiden.

\*The report describes how to build, maintain and use productmodels for the engineering part of building design. In the report a number of Danish and foreign productmodels are described together with examples on the use of information technology in the building industry.

System Analysis is used as a tool to build productmodels, and it is illustrated through modelling in different ways. Different methods for information and function models are compared to each other and to objectoriented methods.

A number of Danish and foreign productmodels for building design are evaluated, and it is concluded that most of the existing models are based on the contractors' point of view. Existing and coming standards for data exchange and classification are described including the STEP standard for exchange of productmodel data.

The common database types - hierarchical, network, relational and object oriented - are described, and the use of standard databases for storing technical and geometric information are discussed.

The use of information technology has increased the need for an automatic data management system, which registers documents, responsibility for data, versions of data etc. The necessity of a common data management system is illustrated through examples.

The author's own construction information model KONIM, which is a building product-model, is described and evaluated. KONIM is based on a principle with references, where only a minor part of the building information is stored in the kernel of the productmodel, while the remaining part of the information is stored through references.

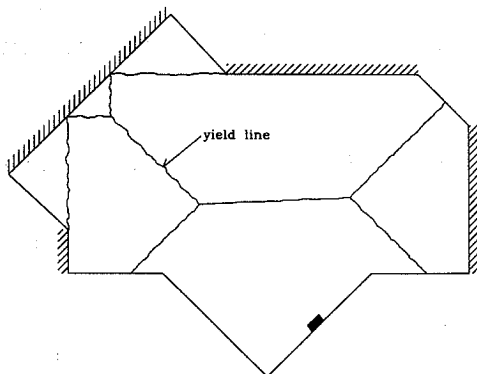
It is concluded that the use of System Analyses, productmodels and software based on databases will be the foundation for further work in order to get a more integrated information handling.

KRENK, S., L. DAMKILDE and O. HØYER: \*Limit Analysis and Optimal Design of Plates with Equilibrium Elements. Journal of Engineering Mechanics, Vol. 120, No. 6, June 1994, pp. 1237-1254. (Reprints available).

\*A finite-element formulation is developed for limit analysis of perfectly plastic plates using triangular equilibrium elements and linear programming. The equilibrium elements are formulated in terms of three moment components at each corner. Equivalent corner forces including shear and torsion moment contributions are derived in a simple vector format. For a linearized yield surface the duality theorem of linear programming leads to dual static and kinematic representation of the solution, whereby the traditional lower bound must be interpreted in terms of the admissibility of the static field. Optimization of material properties, such as the distribution of reinforcement in concrete plates, is also considered. The algorithms are implemented in compact form in a personal computer (PC) environment using a specially developed simplex algorithm for infinite intervals, and examples illustrate the capability of the approach.

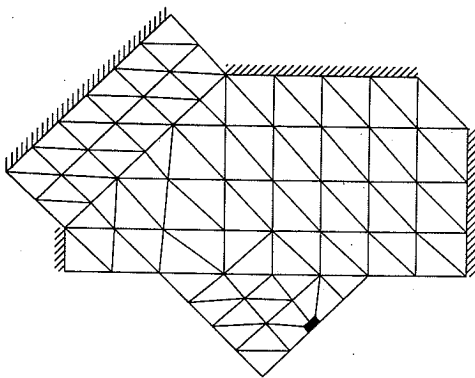
KRENK, S., se også DAMKILDE, L., O. HØYER og S. KRENK

KRENK, S., se også DAMKILDE, L. og S. KRENK



Pladens geometri og brudlinier.

\*Geometry of plate and yield line pattern.



Elementinddeling for plade.

\*Element mesh for plate.

Ref.: KRENK, S., L. DAMKILDE og O. HØYER: Limit Analysis and Optimal Design of Plates with Equilibrium Elements. (s. 28).

KRENK, S., se også JÖNSSON, J., S. KRENK og L. DAMKILDE

KRINGSHOLM, B., se JENSEN, J.-E.B., H. STANG, B. KRINGSHOLM og  
O.H. SØRENSEN

LOPEZ MARTINEZ L., se AGERSKOV, H., R.I. PETERSEN og L. LOPEZ MARTINEZ

MADSEN, HENRIK O., se DITLEVSEN, OVE og HENRIK O. MADSEN

NIELSEN, LEIF OTTO: \*A C++ class library for FEM special purpose software. (Et C++  
klassebibliotek for FEM specialprogrammer). Afdelingen for Bærende Konstruktioner.  
Serie R, nr. 308, 1994. 108 s. Gratis.

\*In the report a C++ class library for development of special-purpose FEM-software balancing  
safety and efficiency requirements is described.

I rapporten beskrives et C++ klassebibliotek til udvikling af elementmetodebaserede  
specialprogrammer i et kompromis mellem sikkerhed og effektivitet.

NIELSEN, LEIF OTTO: Pladers Statik, 4. udgave. (\*Plate Bending, 4th ed. In Danish).  
Afdelingen for Bærende Konstruktioner. Serie F, nr. 141, 1994. 163 s. Kr. 45,-  
excl. moms.

Hensigten er dels at give læseren en forståelse af pladers virkemåde, dels - på grundlag af de  
generelle ligninger - at introducere simple manuelle beregningsmetoder for elastiske pladers  
bøjning, bæreevne af plastiske plader samt pladebuling. Endvidere er Reissner-Mindlin plader  
behandlet.

\*The intention is partly to give the student an understanding of the behavior of plates in bending, partly - on basis of the general equations - to introduce simple manual computational methods for elastic plate bending, limit load for plastic plate bending, and plate buckling. Moreover, Reissner-Mindlin plate bending is treated.

NIELSEN, M.P., se JAGD, LARS, JENS CHRISTOFFERSEN og M.P. NIELSEN

OLSEN, DAVID HOLKMANN: \*Fracture of Concrete - A Test Series. (Brudmekanik for beton - en forsøgsserie). Afdelingen for Bærende Konstruktioner. Serie R, nr. 312, 1994. 61 s. Gratis samt \*Appendix I (Appendix I). Serie R, nr. 313, 1994. 87 s. Gratis.

\*This report contains the results and description of a number of test series carried out in order to evaluate the physical properties and fracture of plain concrete.

The primary aim of this report is to isolate and accurately estimate essential fracture mechanical parameters for a number of properties of concrete cylinders and plain concrete beams.

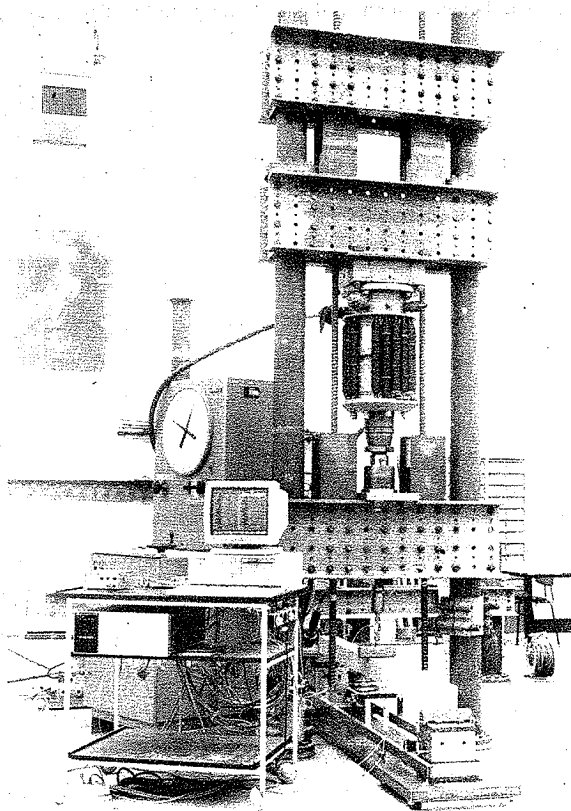
In this investigation a total of 232 test beams together with 714 cylinders are presented containing values of the fracture energy  $G_F$  and flexural strength of concrete for different compressive strength levels, curing conditions, air-content and maximum aggregate size. An investigation of the size effect of beams are performed for normal and high strength concrete.

Furthermore, the full load-deflection curve obtained by a displacement controlled testing machine is given for every beam test carried out.

Denne rapport indeholder resultater og beskrivelser af en række forsøgsserier udført med det formål at vurdere de fysiske brudegenskaber af betonbjælker.

Det primære formål med denne rapport er at isolere og præcist estimere brudmekaniske egenskaber for beton.





Forsøgsopstilling til bestemmelse af brudenergien.

\*The test set-up for fracture energy tests.

Ref.: OLSEN, DAVID HOLKMANN: Fracture of Concrete - A Test Series. (s. 31).

I denne undersøgelse er ialt 232 betonbjælker og 714 betoncylindre afprøvet, og værdier for brudenergien  $G_F$  og bøjningstrækstyrken er præsenteret for forskellige betontrykstyrker, lagringsforhold, luftindhold i betonen og maksimal stenstørrelse i betonen. En undersøgelse af størrelseeffekten for bjælker af normal- og højstyrkebeton er ligeledes foretaget.

Derudover indeholder rapporten den totale last deformationskurve fra en deformationsstyret forsøgsmaskine for samtlige bjælker i forsøgsprogrammet.

OLSEN, JØRGEN FLEMMING, se DAMKILDE, LARS, JØRGEN FLEMMING OLSEN og PETER NOE POULSEN

PETERSEN, R.I., se AGERSKOV, H., R.I. PETERSEN og L. LOPEZ MARTINEZ

POULSEN, PETER NOE, se DAMKILDE, LARS, JØRGEN FLEMMING OLSEN og PETER NOE POULSEN

RANDRUP-THOMSEN, SØREN, se DITLEVSEN, OVE, CLAUS CHRISTENSEN og SØREN RANDRUP-THOMSEN

RESUMÉOVERSIGT 1993: "Summaries of Papers 1993". Afdelingen for Bærende Konstruktioner. Serie R, nr. 310, 1994. 58 s. Gratis.

Resuméer af 30 videnskabelige publikationer m.v., af 1 rapport over eksperimentelle undersøgelser og af 11 eksamensarbejder.

\*Summaries in Danish and English of 30 scientific papers etc., of 1 report on experimental investigations, and of 11 final year projects.

STANG, H.: \*Herbert Krenchel, 40 years of FRC Materials Research. (Herbert Krenchel, 40 års forskning inden for Cementbaserede Kompositmaterialer). Brittle Matrix Composites 4, (eds.: A.M. Brandt and I.H. Marshal). Woodhead Publishing Limited, Warsaw, 1994, pp. 3-6. (Reprints available).

\*The paper is a tribute to the work of Professor Emeritus Herbert Krenchel, Department of Structural Engineering, Technical University of Denmark. The paper was presented at a special session at the Fourth International Symposium on Brittle Matrix Composites (BMC 4), Warsaw, Poland, 1994 in honor of Herbert Krenchel's 70th anniversary. The paper contains a complete list of the references of Herbert Krenchel.

Artiklen er en hyldest til professor emeritus Herbert Krenchels arbejde inden for forskning og udvikling af cementbaserede kompositmaterialer ved Afdelingen for Bærende Konstruktioner, DTU. Artiklen blev præsenteret ved en special-session ved The Fourth International Symposium on Brittle Matrix Composites (BMC 4), Warszawa, Poland, 1994 afholdt i anledning af Herbert Krenchels 70 års fødselsdag. Artiklen indeholder en komplet referenceliste over Herbert Krenchels publikationer inden for området.

STANG, HENRIK og Z. JUN.: \*Experimental Determination of Fatigue Crack Growth in Fiber Reinforced Concrete. (Eksperimentel Bestemmelse af Udmattelsesrevnevækst i Fiberarmeret Beton). Recent Advances in Experimental Mechanics, (eds.: J.F. Silva Gomez et al). A.A. Balkema, Rotterdam, Brookfield, 1994, pp. 1347-1352. (Reprints available).

\*The paper describes a test method for determination of fatigue crack growth in fiber reinforced concrete. Data for fatigue crack growth rate versus number of loading cycles and crack length is obtained through three point bending of steel fiber reinforced concrete beams. Testing was stopped at different stages and crack length was determined by inspection of fluorescent epoxy impregnated polished sections using fluorescence microscopy. At the same

time, the cracking process was investigated indirectly using acoustic emission. In this way both quantitative and qualitative results describing cracking initiation and propagation in fiber reinforced concrete under fatigue load were obtained.

Artiklen beskriver en testmetode til bestemmelse af udmattelsesrevnevækst i stålfiberarmeret beton. Revnevæksthastigheden bestemmes som funktion af antallet af belastningscykler og revnelængde ud fra tre-punkts bøjeforsøg med stålfiberarmede betonbjælker. Forsøgene stoppes på forskellige stadier i belastningshistorien, og revnelængden bestemmes ved visuel inspektion af planslib i bjælken, som er blevet imprægneret med fluorescerende epoxy. Til observationerne benyttes fluorescensmikroskopi. Samtidig bestemmes revneprocessen indirekte ved hjælp af akustisk emission. På denne måde opnås både en kvantitativ og kvalitativ beskrivelse af revneinitiering og revnevækst i fiberarmeret beton under udmattelseslast.

STANG, H., se også GLAVIND, M. og H. STANG

STANG, H., se også JENSEN, J.-E.B., H. STANG, B. KRINGSHOLM og O.H. SØRENSEN

SØRENSEN, O.H., se JENSEN, J.-E.B., H. STANG, B. KRINGSHOLM og O.H. SØRENSEN

VEJRUM, TINA: Vejledning til udmattelsesforsøg i 100 kN-pressen. (\*Instructions for Fatigue Tests with the 100 kN Actuator. In Danish). Afdelingen for Bærende Konstruktioner. Serie I, nr. 112, 1994. 20 s.

Rapporten er en vejledning i udførelsen af udmattelsesforsøg i ABK's 100 kN-presse. Proceduren beskrives fra opstart af pumper, klargøring og montering af prøvelegeme, start af lastpåføring og gagemålinger indtil afslutningen af forsøget og afmontering af prøvelegemet. Belastningen kan være i form af brolast, bølgestlast eller konstant amplitude last.

\*The report is a manual for fatigue tests with the 100 kN actuator at the Department of Structural Engineering. The description covers: Starting up of the hydraulic system, preparation and mounting of the test specimen, loading, strain gage measurements, end of the test and demounting of the test specimen. Different types of loading can be applied: Bridge loading, wave loading or constant amplitude loading.

VROUWENVELDER, A., se DITLEVSEN, O. og A. VROUWENVELDER

ZHANG, JIN-PING: \*Strength of Cracked Concrete. Part 1: Shear Strength of Conventional Reinforced Concrete Beams, Deep Beams, Corbels, and Prestressed Reinforced Concrete Beams without Shear Reinforcement. (Styrken af revnet beton. Del 1: Forskydningsstyrke af jernbetonbjælker, høje bjælker, konsoller og forspændte armerede betonbjælker uden forskydningsarmering). Afdelingen for Bærende Konstruktioner. Serie R, nr. 311, 1994. 106 s. Gratis. /Ph.D./.

\*This report deals with the shear strength of reinforced concrete beams without shear reinforcement determined by means of the theory of plasticity.

It has been observed that in general the shear failure of non shear reinforced concrete beams is characterized by the formation of a critical diagonal crack. In this paper, a physical explanation is given for this fact under the hypothesis that the cracking of concrete introduces potential yield lines which may be more dangerous than the ones found by the usual plastic theory. The shear strength of cracked concrete is expressed by introducing a reduction factor which reflects the reduction of sliding strength due to cracking.

Conventional reinforced concrete beams, subjected to both concentrated loading and uniform loading, deep beams and corbels, and prestressed beams are studied. The theoretical calculations are compared with experimental results reported in the literature.

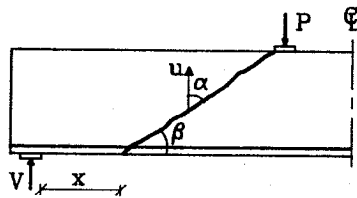
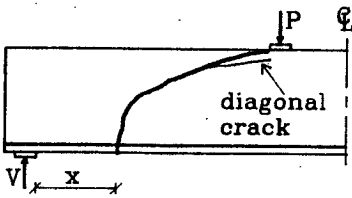
A good agreement has been found.

Denne rapport behandler bæreevnen af armerede betonbjælker og betonplader uden forskydningsarmering bestemt v.h.a. plasticitetsteorien.

Forskydningsbrud i ikke forskydningsarmerede bjælker og plader er karakteriseret ved, at der dannes en såkaldt kritisk diagonal revne. I rapporten gives en fysisk forklaring på dette fænomen, der går ud på, at revnedannelse i betonen introducerer potentielle brudlinier eller flydelinier, som kan være farligere end dem, der findes v.h.a. sædvanlig plasticitetsteori. Glidningsmodstanden i en revne beregnes ud fra glidningsmodstanden i urevnet beton v.h.a. en reduktionsfaktor.

Både slapt armerede bjælker påvirket af koncentreret last og jævnt fordelt last, høje bjælker, konsoller og forspændte bjælker og plader studeres. De teoretiske resultater sammenlignes med forsøgsresultater fra litteraturen.

Der er fundet god overensstemmelse.



Kritisk diagonalrevne og brudlinie.

Simplificeret kritisk diagonalrevne og brudlinie.

\*Critical diagonal crack and yield line.

\*Simplified critical diagonal crack and yield line.

Ref.: ZHANG, JIN-PING: \*Strength of Cracked Concrete. (s. 36).

## 2. RAPPORTER OM EKSPERIMENTELLE UNDERSØGELSER

### \*Reports on experimental investigations

Rapporterne i denne gruppe drejer sig specielt om eksperimentelle undersøgelser. Der kan være tale om rekvirerede undersøgelser (med tilsvarende rapporter i S-serien) eller om andre rapporter om eksperimentelle undersøgelser, som ikke udkommer i serierne R, F eller I.

\*These reports deal with experimental investigations. They may be reports on contract work (the S-series), or they may be other reports on experimental investigations, which are not published in the R, F, or I series.

Deformationsstyret Trykprøvning af Udborede Betoncyindre. (\*Deformation Controlled Compressive Testing of Concrete Cores. In Danish). ABK, serie S nr. 9408.

Rapporten beskriver en serie forsøg udført for Vejdirektoratet, København. Formålet med forsøgene var at bestemme den fuldstændige arbejdskurve under trykpåvirkning for i alt 31 udborede betoncyindre fra 11 forskellige lokaliteter.

Udover forsøgsresultaterne beskrives forsøgsopstillingen, som muliggør bestemmelse af den fuldstændige arbejdskurve for højstyrkebetoner (styrker over 130 MPa). Ved forsøgene benyttes omkredstøjningen som feed-back signal i en closed loop forsøgsopstilling i en Instron 8508 universalprøvemaskine med en kapacitet på 5 MN.

Rekvirent: Vejdirektoratet.

Yderligere oplysninger: Henrik Stang.

\*The report describes a test series carried out for the Danish Road Directorate in Copenhagen. The purpose of the tests was to determine the complete stress-strain curve in compression for a total of 31 concrete cores from 11 different sites.

Apart from the test results a test setup is described which makes possible the determination of the complete stress-strain curve for high strength concretes (strengths above 130 MPa). In the test setup a circumferential strain signal is used as feedback signal in a closed loop test setup in an Instron 8508 universal testing machine with a capacity of 5 MN.

Client: Vejdirektoratet.

Further information: Henrik Stang.

\*Vertebral Body Strength and Deformation Characteristics. (Ryghvirvlers Styrke og Deformationsegenskaber. In English). ABK, Serie S nr. 9414.

\*The present report describes a series of tests carried out for Novo Nordisk A/S, Bagsværd, Denmark. The purpose of the tests was to determine the ultimate compressive load carrying capacity of a number of vertebral bodies from 14 different deceased persons. Furthermore, to



obtain the load/strain curve for each vertebral body in order to be able to determine the deformation characteristics of each body. Apart from describing the test results the report describes the test setup used. All tests were carried out in an Instron 8502 universal testing machine.

Client: Novo Nordisk A/S.

Further information: Henrik Stang.

Rapporten beskriver en serie forsøg udført for Novo Nordisk A/S, Bagsværd. Formålet med forsøgene var at bestemme trykbrudlasten for et antal ryghvirvler fra 14 forskellige afdøde personer. Desuden at bestemme kraft/deformations-kurven for hver ryghvirvel for at kunne karakterisere deformationsegenskaberne. Ud over at beskrive forsøgsresultaterne beskrives den benyttede forsøgsopstilling. Samtlige forsøg blev udført i en standard Instron 8502 universalprøvemaskine.

Rekvirent: Novo Nordisk A/S.

Yderligere oplysninger: Henrik Stang.

### 3. EKSAMENSPROJEKTER

#### \*Final year projects

Da disse afhandlinger kun findes i et enkelt eksemplar, må et nærmere studium af dem foregå på Afdelingens bibliotek efter forudgående aftale. Fotokopier af hele afhandlinger eller dele heraf kan leveres til en pris af kr. 1,00 pr. side.

Yderligere oplysninger om afhandlingernes indhold fås ved henvendelse til den under resumeet angivne lærer.

Anmodning om kopiering kan ske telefonisk på tlf. 45 25 25 25.

\*As there is normally only one copy of each of these theses, anyone wishing to study them in detail must do so at the Department's library according to a previous arrangement. Photocopies of entire theses or parts thereof can, however, be supplied at a price of D.kr. 1.00 per page. Orders for copies must be accompanied by a cheque for the amount in question.

Further information on the content of the theses can be obtained by application to the project leader indicated under the summary.

AGRATI, STEFANO: \*Estimation of Structural Parameters from Ambient Vibration Test. (In English). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, December 1994, 172 s. Fotokopi, kr. 172,-.

\*The scope is to verify the reliability of various techniques of estimation of the modal parameters of elastic structures such as cable stayed or suspension bridges and tall buildings. Estimations were drawn from records of vibrations due to wind loading.

The research has considered two techniques in the frequency domain and one technique in the time domain: in the first case the spectrum of the response of the structure to wind loading has been fitted with the theoretical mechanical admittance function of a linear visco-elastic one degree of freedom system by a least-squares technique, while in the second frequency domain case, the same system has been fitted by a maximum likelihood technique.

The time domain technique used was the so called Random Decrement Technique (RDD).

Project leader: Claës Dyrbye.

BEISKJÆR, SIMON BJØRN og THOMAS JOHANNSEN: Stabilitet og tyndvæggede bjælker. (\*Stability of thin-walled beams. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994, 144 s. hovedrapport + bilagsrapport. Fotokopi, kr. 144,-.

I projektet opstilles en elementmetodeformulering til beregning af rammekonstruktioner opbygget af tyndvæggede bjælkeelementer. Beregningsmetoderne omfatter både fuldt geometrisk ikkelineære analyser samt asymptotiske beregninger til bestemmelse af stabilitetslasten og postbucklingopførslen.

Lærer: Lars Damkilde.

\*In the project a finite element method is established for the analysis of frame structures with thin-walled beam elements. The methods include both a full nonlinear geometric analysis and

an asymptotic calculation, which determines the classical stability load and the post-buckling behavior.

Project leader: Lars Damkilde.

BENDIXEN, SØREN, se LARSEN, CHARLOTTE NØRGAARD og SØREN BENDIXEN

BLAK-NIELSEN, JEPPE, se KNUDSEN, JESPER KYHL og JEPPE BLAK-NIELSEN

CARLSEN, ROLF: Udmattelse i stålbrodæk udsat for stokastisk last. (\*Fatigue in steel bridge deck under random loading. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994, 129 s. + 36 s. app. Fotokopi, kr. 165,-.

I projektet er undersøgt udmattelse i et stålbrodæk, der udsættes for svingninger hidrørende fra vindlast. Som eksempel er valgt at se på brobanen i skråstagsbroen Pont de Normandie i byggefasen. Der er som vindlast benyttet en 50-års storm af 5 dages varighed. På grundlag af en computersimulering af brobanens respons er bestemt spændingsvariationerne under denne storm, og denne spændingshistorie er anvendt i udmattelsesforsøgene i projektet.

Lærere: Claës Dyrbye og Henning Agerskov.

\*The project deals with fatigue in a steel bridge deck subjected to vibrations due to wind loading. As an example, the bridge deck structure of the cable-stayed bridge Pont de Normandie during construction is investigated. The wind loading used is a 50-years storm of 5 days duration. On the basis of a computer simulation of the response of the bridge deck, the stress variations during this storm have been determined, and this stress history has been used in the fatigue tests.

Project leaders: Claës Dyrbye and Henning Agerskov

COLLETTE, FRÉDÉRIC SÉBASTIEN: Svingsningsdæmpning af rammekonstruktion ved anvendelse af teknisk enkle foranstaltninger. (\*Vibration damping of a three-storey building-model with resonant appendages. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994. Hovedrapport s. 53 og forsøgsrapport s. 44. (Bilagrapport s. 243). Fotokopi, kr. 97,-.

Plan tre-etagers stålrammekonstruktion (1,3 m høj, 0,5 m bred). Teoretisk og forsøgsmæssig undersøgelse af strukturens respons til harmonisk belastning omkring dens første egenfrekvens ved anvendelsen af diverse foranstaltninger.

En massedæmper opbygges som en vogn, der kan køre på en etage og som er fastgjort med fjedre til rammen. Dens samlede masse vælges til 1% af selve konstruktionens. Optimeringen af foranstaltningens dæmpende effekt på rammens respons udføres ved en regulering af dens egenfrekvens og etageplacering.

En impact-dæmper opbygges som en kasse, der er fikseret på en etage, og hvori der frit placeres en kugle, hvis masse vælges til 0,5% af selve konstruktionerne. Optimeringen af foranstaltningens dæmpende effekt udføres ved en regulering af den maksimale afstand mellem kugle og stødpude samt de elastiske stødegenskaber af væggene ved anvendelse af forskellige stødpuder.

Endelig undersøges det kombinerede system, hvor impact-dæmperen fikseres på masse-dæmperens vogn. Systemets samlede masse vælges til 1% af selve konstruktionen. Optimeringen udføres ved en regulering af impact-dæmperens parametre samt masseforholdet mellem kugle og vogn. Hvor de to første systemer er kendte, har det kombinerede system meget gode svingsningsdæmpningsegenskaber uden at involvere komplicerede tekniske foranstaltninger såsom hydrauliske dæmpere eller gener fra direkte accelerationsoverførelse.

Lærer: Claës Dyrbye.

\*Plane three-storey building-steelmodel (1,3 m high, 0,5 m wide). Theoretical and experimental investigation of the response of the structure with special appendages for harmonic excitation around the structure's first eigenfrequency.

A mass damper is composed of a wagon, rolling on one of the stories and fixed to the structure with springs. The mass of the system is set to 1% of the total mass of the structure. The optimum of the system's damping effect on the response of the structure is found by tuning of the system's egenfrequency and story-choice.

An impact damper is composed of a box fixed on one of the stories and in which a steel-ball is placed. The ball mass is set to 0,5% of the total mass of the structure. The optimum of the system's damping effect is found by regulating the maximum distance between the ball and the impact cushion, as well as the elasticity of the impacts by varying cushions.

Finally, a combined system is investigated, where the impact damper is fixed on the wagon of the mass damper. The total mass of this system is set to 1% of the structure's mass. The optimum is found by regulating the parameters of the impact damper as well as the ratio between the mass of the ball and the wagon. Whereas the two first systems are known, the combined system has a very good response-damping effect without involving the use of complicated technical systems such as hydraulic dampers, or the problems caused by straight acceleration transfer.

Project leader: Claës Dyrbye.

DELA, BIRGITTE FRIIS: Svindrevner i Højstyrkebeton. (\*Shrinkage Cracking in High Strength Concrete. In Danish). Eksamensprojekt, Afdelinge for Bærende Konstruktioner, 1994, i samarbejde med Laboratoriet for Bygningsmaterialer. Hovedrapport (101 sider + Appendiks). Fotokopi, kr. 101,-.

Projektet har til formål at undersøge, hvorvidt forøget svind i cementpasta fremkaldt af tilsætning af mikrosilika kan fremkalde mikrorevnedannelse omkring tilslag. Projektet omfatter en indledende eksperimentel del, hvor de mekaniske egenskaber (styrke, stivhed og brudenergi) som funktion af hærdeforløbet bestemmes for 2 forskellige cementpastaer med og uden mikrosilika. Endvidere bestemmes det autogene svind for de to cementpastaer. Efter de indledende eksperimentelle undersøgelser følger et teoretisk afsnit, som behandler spændings-tilstanden omkring et tilslag i en cementpasta som svinder. Der opstilles forskellige kriterier

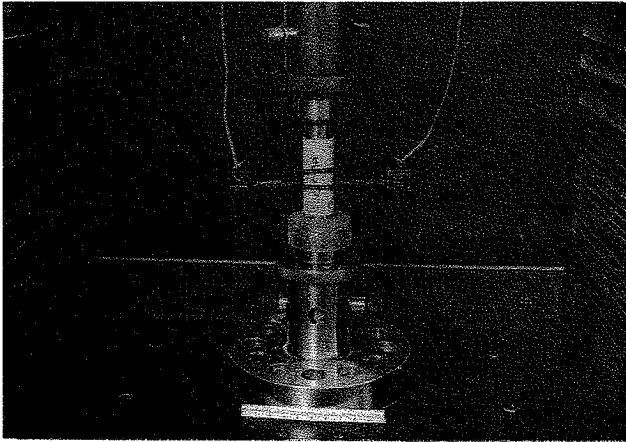
for revnedannelse i pastaen. Afslutningsvis undersøges mikrorevnedannelsen i to betoner ved hjælp af tyndslibsteknik. Der konstateres mikrorevnedannelse i betonen med størst autogent svind, og der konstateres god overensstemmelse mellem de udviklede modeller og de foretagne eksperimenter.

Lærere: Kurt Kielsgaard Hansen (LBM) og Henrik Stang (ABK).

\*The purpose of the project is to investigate whether increased shrinkage induced by addition of micro-silica can be the source of micro-cracks around aggregate. The project includes an experimental part where the different mechanical properties (strength, stiffness and fracture energy) as functions of the hardening process are determined for two different cement pastes with and without microsilica. Furthermore, the autogenous shrinkage is determined for the two cement pastes with and without microsilica. After the experimental investigations follows a theoretical section which treats the state of stress and strain around an aggregate in a cement paste under shrinkage. Different criteria for formation of cracks in the paste are set up. Finally, the micro-crack development in two concretes are investigated using thin sectioning technique. Microcrack formation is found in the concrete with the largest autogenous shrinkage and a good agreement is found between the models developed and the experiments carried out.

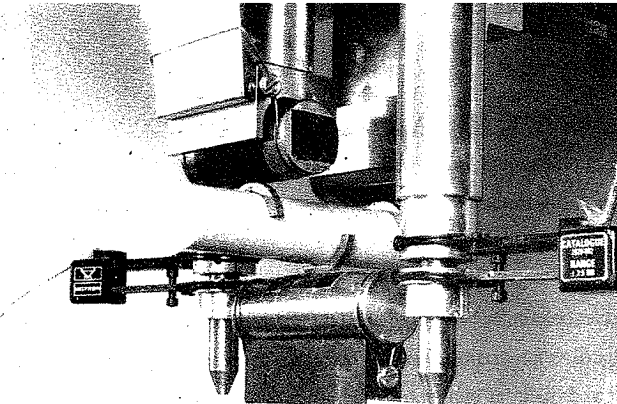
Project leaders: Kurt Kielsgaard Hansen (LBM) and Henrik Stang (ABK).

JOHANNSEN, THOMAS, se BEISKJÆR, SIMON BJØRN og THOMAS JOHANNSEN



Forsøgsopstilling til bestemmelse af elasticitetsmodul for cementpasta (trykprøvning).

\*Test set-up for determination of modulus of elasticity of cement paste (compression test).



Forsøgsopstilling til bestemmelse af bøjningstrækstyrken af cementpasta.

\*Test set-up for determination of the bending tensile strength of cement paste.

Ref.: DELA, BIRGITTE FRIIS: Svindrevner i højstyrkebeton. (s. 45).



KNUDSEN, JESPER KYHL og JEPPE BLAK-NIELSEN: Neddykkede, flydende tunneler.

(\*Submerged, floating tunnels. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner og Institutet for Strømningsmekanik og Vandbygning, 1994, 184 s. hovedrapport + bilagsrapport. Fotokopi, kr. 184,-.

I projektet undersøges neddykkede, flydende tunneler som alternativ til konventionelle broforbindelser eller tunneler. Konceptet består af et rørformet profil med positiv opdrift forankret til havbunden med kabler. Udover de sædvanlige påvirkninger undersøges indflydelse fra bølger og strøm, herunder resonansfænomener.

Lærere: N.J. Gimsing, J. Fredsøe og L. Damkilde.

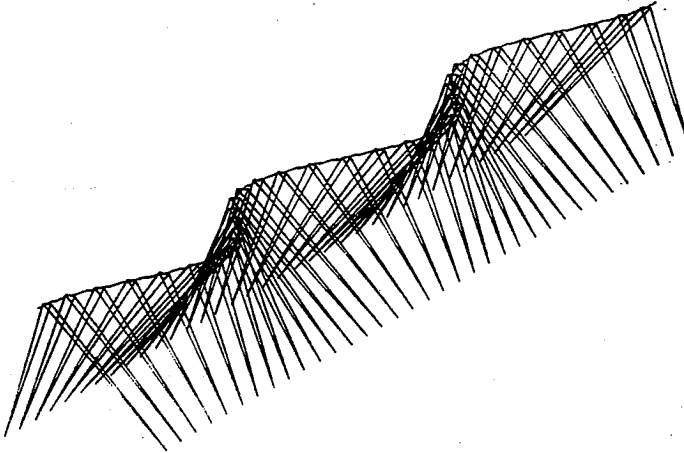
\*In the project submerged, floating tunnels are investigated as an alternative to conventional bridges or tunnels. The concept consists of a tube formed profile with positive buoyancy anchored to the sea bed with cables. In addition to the normal loading conditions, loads from waves and stream are considered also in relation to structural resonance.

Project leaders: N.J. Gimsing, J. Fredsøe and L. Damkilde.

LARSEN, CHARLOTTE NØRGAARD og SØREN BENDIXEN: EDB-beregninger af

fiberarmeret betonvejbelægning. (\*FEM-calculations of Fiber Reinforced Concrete Pavement. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994, 74 s. hovedrapport + 47 s. bilagsrapport. Fotokopi, kr. 121,-.

Eksamensprojektet behandler beregning af en tynd kontinuert armeret og fiberarmeret betonbelægning udviklet til vejreparationsformål. Beregningen er baseret på en elementmetodemodel, som er opstillet ved hjælp af elementmetodeprogrammet LUSAS. Beregningen er udført dels som en lineær beregning og dels som en ikke-lineær beregning, idet materialets ikke-lineære



Egensvingsningsform af neddykket tunnel fastholdt af kabler.

\*Mode of vibration of submerged floating tunnel anchored by cables.

Ref.: KNUDSEN, JESPER KYHL og JEPPE BLACK-NIELSEN: Neddykkede, flydende tunneler. (s. 48).

opførelse tages i regning. Som belastninger undersøges såvel hjultryk, temperaturpåvirkning og svind. Output fra beregningerne formuleres som design-krav til materialet. Konklusionerne på arbejdet sættes i relation til lignende beregninger udført i det EU-støttede (BRITE) forskningsprojekt NEWPAVE.

Lærer: Henrik Stang.

\*The project concerns the calculation of a thin continuously reinforced and fiber reinforced concrete overlay developed for pavement repair purposes. The calculation is based on a finite element model which is set up using the commercial finite element package LUSAS. The calculations are carried out as linear as well as non-linear calculations taking the material non-linearities into account. The following loads are considered in the calculations: wheel-load, temperature loading, and shrinkage. The output from the calculations is formulated

as requirements on the material properties. The conclusions are related to similar calculations carried out in the EU-supported (BRITE) research project NEWPAVE.

Project leader: Henrik Stang.

LUND, NUNGO MØLLER, se SEHESTED, PALLE DUEHOLM og NUNGO MØLLER  
LUND

OLSEN, JØRGEN FLEMMING og PETER NOE POULSEN: Stabilitet og Postbuckling af Pladekonstruktioner (\*Stability and Postbuckling of Plate Structures. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994, 188. s. Fotokopi, kr. 188,-.

Projektet omhandler metoder til beregning af stabilitetsproblemer i lineært-elastiske pladekonstruktioner. Der er foretaget en generel elementmetodeformulering af beregningsmetoderne, som er opstillet for såvel perfekte som imperfekte konstruktioner. Beregningsmetoderne omfatter:

- Singlemode-analyse med henholdsvis lineær og ulineær prebuckling
- Multimode-analyse med lineær prebuckling
- Fuldt ulineære beregninger

Singlemode- og Multimode-analyse er asymptotiske metoder, der i forhold til fuldt ulineære elementmetodeberegninger har et beskedent beregningsomfang. De opstillede beregningsmetoder er implementeret, og der er foretaget konstruktionsberegninger, hvor de forskellige metoder er sammenlignet.

Generelt giver de asymptotiske metoder resultater, der er i god overensstemmelse med fuldt ulineære beregninger.

Lærere: Lars Damkilde og Esben Byskov.

\*The project deals with computational methods for stability problems in linear elastic plate structures. A general finite element formulation has been established for both perfect and imperfect structures. The computational methods include:

- Singlemode-analysis with respectively linear and non-linear prebuckling.
- Multimode-analysis with linear prebuckling.
- Full non-linear analysis.

The singlemode and multimode analysis are asymptotic methods with modest computational costs compared to a full non-linear analysis.

The computational methods have been implemented and comparisons are made between the different types of analysis.

In general the results for asymptotic methods are in good agreement with full non-linear analysis.

Project leaders: Lars Damkilde and Esben Byskov.

POULSEN, PETER NOE, se OLSEN, JØRGEN FLEMMING og PETER NOE POULSEN

SEHESTED, PALLE DUEHOLM og NUNGO MØLLER LUND: Stagbrud i skråstagsbroer.

(\*Rupture of a guy cable of a cable-stayed bridge. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1994, 139 s. Fotokopi, kr. 139,-.

Mulige hændelsesforløb (*scenarier*), der vurderes at kunne føre til stagbrud er beskrevet og evalueret. På baggrund heraf er undersøgelsen koncentreret om det momentane stagbrud.

Den forudsatte bro er en 3-spændskonstruktion med et hovedfag på *288 meter* og sidefag på *120 meter*.

Der er bestemt dynamiske lastfaktorer, svarende til brud af udvalgte repræsentative stag og for tre forskellige afstivningsdrager-konstruktioner, *komposit, stål og beton*.

De fundne dynamiske lastfaktorer for de forudsatte brokonstruktioner udviser en tydelig tendens til at antage værdier betydeligt under 2,0. Således synes en værdi på 1,3 - 1,4 at være undersøgelsens hovedresultat.

For at vurdere, om stagbruddet kan være en dimensionerende påvirkning af de tre forskellige afstivningsdragere, indføres der en regningsmæssig sammenhæng svarende til ulykkeslastkombinationen.

Denne lastkombination sammenlignes med trafiklastkombinationen, der normalt vil være dimensionerende med hensyn til bøjningspåvirkning.

Den foretagne sammenligning viser, at for komposit- og især beton-afstivningsdragere vil ulykkeslastkombinationen med stagbrud antagelig være dimensionerende.

Lærere: Claës Dyrbye og Niels J. Gimsing.

\*Possible scenarios which might lead to rupture of a guy cable are investigated. As a consequence, the analysis is concentrated on a momentaneous rupture. The bridge has 3 spans, a 288 m main span and 2 side spans, each 120 m. Dynamic load factors are found at ruptures of some representative cables and for 3 different stiffening girders, composite, steel, and concrete.

The dynamic load factors for the different bridge structures tend to be significantly less than 2. A value of 1.3 - 1.4 comes out as a main result.

In order to evaluate if the stay rupture may be a decisive action in the design of the 3 different stiffening girders, it is introduced by its design value corresponding to accidental load combination. This is compared with the load combination with traffic load, which usually is decisive with regard to bending.

The comparison shows that in particular for a concrete girder but also for a composite girder, this accidental load combination tends to be the most important.

Project leaders: Claës Dyrbye and Niels J. Gimsing.

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