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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 1992 to 30th June 1993, 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, HENNING and N. THOUGÅRD PEDERSEN: \*Fatigue Life Prediction of Offshore Steel Structures under Spectrum Loading. (Bestemmelse af udmattelseslevetiden for offshore stålkonstruktioner under spektrumlast). International Institute of Welding, Annual Assembly, Haag, July, 1991, IIW Doc. XIII-1411-91, 18 pp. (Reprints available).

\*The fatigue life of offshore steel structures under spectrum loading is studied in the present investigation. Fatigue test series with various types of stochastic loading that are realistic in relation to offshore structures have been carried through. The experimental investigation comprises both test series on full-scale tubular joints and test series on smaller welded test specimens. The test series that have been carried through until now show a significant difference between constant amplitude and variable amplitude fatigue test results. For the welded plate test specimens, approx. 100 fatigue tests have been carried out, and the values of the Miner sum that were obtained in the variable amplitude test series, generally vary in the range 1/3 to 2/3. For the full-scale tubular joints, the number of test results is at present too limited to draw final conclusions. However, the results obtained until now indicate a value of the Miner sum of  $M \sim 0.8$  for the variable amplitude tests.

AGERSKOV H. se også PEDERSEN, N. THOUGÅRD og HENNING AGERSKOV

ANDREASEN, BENT S. and M.P. NIELSEN: \*Arch effect in reinforced concrete one-way slabs. (Membranvirkning i enkeltspændte armerede betonplader). Afdelingen for Bærende Konstruktioner. Serie R, nr. 275, 1991. 24 s. Gratis.

\*It is well known that the load carrying capacity of reinforced concrete slabs with horizontal restraints can be several times that found by the yield line theory.

The way in which the theory of perfectly plastic materials can be used to derive expressions for the load carrying capacity for reinforced concrete slab strips with horizontal restraints at the edges will be demonstrated here.

For slab strips, the deflection at maximum load is a very important parameter. A simple expression for the deflection as a function of the slenderness of the slab is derived.

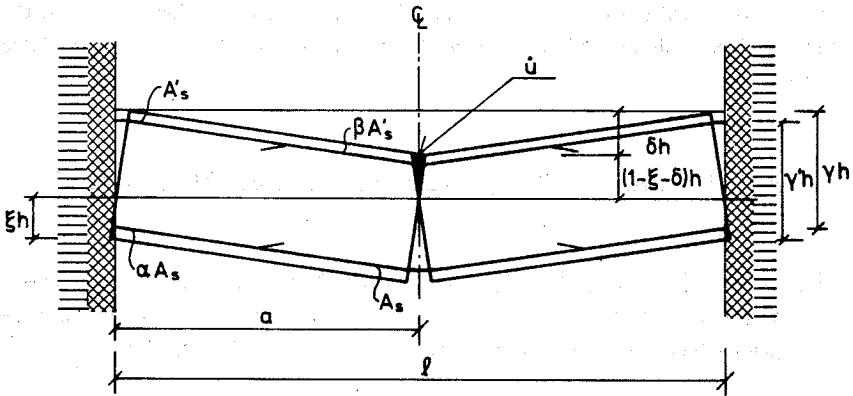
The theory is compared with test results and the agreement is found to be satisfactory.

Det er velkendt, at bæreevnen af armerede plader med vandrette fastholdelser kan være flere gange større end bæreevnen fundet ved brudlinieteorien.

Det vil her blive demonstreret, hvordan teorien for stift plastiske materialer kan benyttes til opstilling af udtryk for bæreevnen af armerede enkeltspændte betonplader med vandret fastholdelse ved understøtningerne.

For pladestrimler specielt er udbøjningen ved maksimal last en meget vigtig størrelse. Der er her opstillet et simpelt udtryk til beregning af udbøjningen som funktion af pladens slankhed.

Den opstillede teoretiske model er sammenlignet med forsøgsresultater, hvor der er fundet god overensstemmelse.



Pladestrimmel med nedbøjning  $w = \delta h$  ved midten og træk- og trykarmering.

\*Slab strip with a deflection  $w = \delta h$  in the middle, and tension and compression reinforcement.

Ref.: Andreassen, Bent Steen og M.P. Nielsen: Arch effect in reinforced concrete one-way slabs. (s. 5).

ANDREASEN, BENT, S., se også GANWEL, CHEN, BENT S. ANDREASEN og M.P. NIELSEN

ARNBJERG-NIELSEN, T.: \*Rigid-ideal plastic model as a reliability analysis tool for ductile structures. (Den stift-idealplastiske model som værktøj for pålidelighedsanalyse af konstruktioner med sejt svigt). Afdelingen for Bærende Konstruktioner. Serie R, nr. 270, 1991. 100 s. Gratis. /Lic./.

\*The applicability of the rigid-ideal plastic material model for structural reliability analysis is investigated. This model has, due to the transparency of the principles of the lower and upper bound theorem, been widely used in the reliability analysis literature.

Based on the upper bound theorem of plasticity theory two reliability methods are outlined. Both methods are analyzing rigid-ideal plastic systems with respect to plastic collapse. Usually only very few collapse mechanisms contribute significantly to the total probability of collapse. The purpose of the methods is to identify these few mechanisms. The first method is based on the polyhedral substitute yield conditions and is usable for multi-dimensional yield conditions, assuming all the random variables are Gaussian and the dissipation is linear in the yield strengths. These two restrictions are removed from the second method, in which the only restriction is an operational transformability of the random variables into the Gaussian space. This second method, which is based on non-linear minimization, is illustrated by 3 examples.

An investigation of the practicability of analyzing non rigid-ideal plastic systems by the use of the rigid-ideal plastic model has been made. For a specific linear-elastic beam structure, where the beams are connected through strain softening yield hinges, an introduction of a model uncertainty, an effectivity factor, has lead to a simple method, so that the reliability analysis can be made using a rigid-ideal plastic model. The evaluation of the effectivity factor is based upon a sum of a linear regression and a Gaussian residual, and it requires only a few deterministic evaluations by use of the real beam model. The method has given promising results, as can be seen when compared to simulation results for the real beam model.

Anvendelsesmuligheder for den stift-idealplastiske materialemodel inden for bærende konstruktioners sikkerhed er undersøgt. Denne model har vundet stor udbredelse i sikker-



hedsanalysen, især på grund af øvre- og nedreværdisætningens simpelhed.

Med udgangspunkt i øvre- og nedreværditeoremet er to pålidelighedsmetoder beskrevet. Begge metoder analyserer stift-idealplastiske systemer med hensyn til plastisk kollaps. Normalt bidrager kun få svigtmekanismer væsentligt til den totale svigtsandsynlighed. Formålet med metoderne er at bestemme disse få mekanismer. Den første metode baserer sig på polygonale substitutflydebetingelser og kan anvendes for flerdimensionale flydebetingelser, under forudsætning af, at de stokastiske variable er gaussiske, og at dissipationen er lineær i styrkevariablerne. Disse to begrænsninger er fjernet i den anden metode, som kun forudsætter, at det skal være praktisk muligt at transformere de stokastiske variable ind i et gaussisk rum. Denne sidste metode, som er baseret på ikke-lineær optimering, er illustreret gennem 3 eksempler.

En undersøgelse af mulighederne for at analysere ikke stift-idealplastiske systemer ved hjælp af den stift-idealplastiske model er udført. Med udgangspunkt i en lineær-elastisk bjælkekonstruktion, hvor bjælkerne er sat sammen via flydede, i hvilke momentet aftager som funktion af den gensidige vinkeldrejning, er der gennem indførelse af en modelusikkerhed, en effektivitetsfaktor, opstillet en simpel metode, således at en pålidelighedsanalyse kan baseres på den stift-idealplastiske model. Metoden til evaluering af den stokastiske effektivitetsfaktor er baseret på en sum af en lineær regression og et gaussisk residual, og kræver kun få beregninger med den virkelige bjælkekonstruktion. På grundlag af sammenligning med simuleringresultater for den virkelige model, kan metoden hævdes at have givet lovende resultater.

ARNBJERG-NIELSEN, T. and O. DITLEVSEN : \*Rigid-Ideal Plastic System Reliability. In "Reliability and Optimization of Structural Systems '90" (eds. A. Der Kiureghian and P. Thoft-Christensen), Lecture Notes in Engineering, Springer Verlag, pp. 13-21, 1991. Proc. of the 3rd IFIP WG 7.5 Working Conference on Reliability and Optimization of Structural Systems, Berkeley, Ca., March 1990. (Reprints available).

\*A method for upper bound approximations to the reliability with respect to rigid-ideal plastic structural collapse is presented. Usually only very few collapse mechanisms contribute significantly to the total probability of collapse. The problem is therefore to identify these few mechanisms. The method is illustrated for a spatial frame structure discrete

tized into a finite number of potential yield hinges. Each potential yield hinge is modeled individually by assigning to it any general piecewise differentiable yield surface. The associated flow rule is assumed to be valid in all hinges. Yield strengths and loads are random without restrictions on the choice of the joint distribution except for operational transformability into the standard Gaussian space. It is shown how the problem of search for significant collapse mechanisms can be formulated as a standard constrained non-linear minimization problem.

ASKEGAARD, V.: \*Prediction of Initial Crack Location in Welded Fatigue Test Specimens by the Thermoelastic Stress Analysis Technique. (Forudsigelse af Forventet Brudsted i Svejste Prøvelegemer gennem Anvendelse af den Thermoelastiske Måleteknik). Afdelingen for Bærende Konstruktioner. Serie R, nr. 276, 1991. 9 s. Gratis.

\*In the paper tests are described to compare prediction of initial crack positions using the thermoelastic technique with fractographic observations in welded fatigue test specimens.

Correspondence between positions predicted to be possible origins for crack formation obtained by thermoelastic SPATE observations and the actual positions found by fractography of the rupture surfaces is considered to be good.

This indicates that the SPATE technique may be useful in predicting "hot spots" in welded structures. The tests also illustrate that the technique gives useful information about crack development during a test with only visual contact to the surface of the specimen.

DAMKILDE, L. and S. KRENK: \*Influence from residual stresses on the buckling strength of thin-walled cold-formed column elements. In proceedings of 1991 ECCS, Nordic Steel Colloquium. European Convention of Structural Steelwork Annual Meeting, pp. 229-236, 1991.

\*Cold-formed steel channel struts are often used as structural elements in light-weight steel structures. The buckling capacity of the individual member is an important design

parameter. Depending on free length and the support conditions the elements may fail in bending or combined bending–torsion due to the low torsional stiffness.

Recently experiments were carried out at The Danish Building Research Institute, (SBI). The tests included both individual struts supported by a loosely fitted single bolt at each end and a full roof truss. The results indicate a considerable effect of residual stresses from the cold–forming process.

Available results for residual stresses in cold–formed sections indicate the dominating influence of the thickness–bending component. This effect is incorporated in a simple computational model that compares well with the bending instability test results. The paper is a preliminary study for a more general numerical method including bending–torsion instability and a detailed representation of the displacement field.

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

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

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

DITLEVSEN, O.: \*Random field interpolation between point by point measured properties. In Computational Stochastic Mechanics (eds. P.D. Spanos and C.A. Brebbia), Computational Mechanics Publications and Elsevier Applied Science, pp. 801–812, 1991. Proc. of the 1st international conference on computational stochastic mechanics, Corfu, Greece, September 1991. (Reprints available).

\*Computational practicability imposes strong restrictions on the choice of a random field model for stochastic interpolation (kriging) between measured values of a material property, say, at a large set of points in a material body. With background in an actual example of a large number of cone tip resistance measurements in clay till it is demonstrated that pragmatic considerations lead to an almost unique mathematical structure of the model. The problem of pragmatism originates from the necessity of being able to invert a very large covariance matrix a large number of times. In order to appreciate this a general introduction to random field interpolation is given.

DITLEVSEN, O.: \*Gaussian excited elasto-plastic oscillator with rare visits to the plastic domain. Journal of Sound and Vibration, Vol. 145, No. 3, pp. 443-456, 1991. (Reprints available).

\*The probabilistic properties are modelled of the plastic displacement process component and the plastic work process of the response of a symmetric linear elasto-plastic oscillator excited by a stationary Gaussian process. Under the assumption of rare visits to the plastic domain these processes are taken to be homogeneous compound Poisson processes. The intensity and the jump statistics are derived by use of Slepian model process theory from the crossing properties at the elastic limits of the associated stationary Gaussian response and the corresponding Cramér-Leadbetter envelope process. The word "associated" refers to the linear elastic oscillator obtained from the elasto-plastic oscillator by letting the elastic limit go to infinity. Finally, an asymptotic distribution of the time to first passage of a given level is reported for each of the two compound Poisson processes.

DITLEVSEN, O.: \*Boulders in the till of Great Belt. Composition of size and density of occurrence. Bulletin of the Geological Society of Denmark, Vol. 39, No. 3-4, 1991. (Reprints available).

\*The topic is about the density of occurrence of boulders and the composition of boulder sizes in the till deposits of the Great Belt region. The investigation has been made on the initiative of AS Storebæltsforbindelsen in order to prepare for making a bored tunnel through the till deposit. Geographical universality has been revealed of the composition law of boulder sizes observed on the cliff beaches. It is found that the joint composition law of the three principal axes of the boulders has a surprisingly simple structure. In particular, the maximal dimension has an exponential composition law. Different details of the statistical analysis give support to several causal conjectures about the glacial mechanism of boulder deposition. Seismic diffraction measurements of boulder locations have also been made. A corridor has been considered along the future bored tunnel alignment chosen by AS Storebæltsforbindelsen. These measurements give no information about the sizes of the boulders. However, by using the universal results for the beach regions in the analysis of the seismic data it turns out to be possible to conjecture about the densi-

ty of larger boulders in the till deposit within the corridor.

DITLEVSEN, O.: \*Bayesian decision analysis as a tool for structural engineering decisions. Joint Committee on Structural Safety, Working Document, Publisher: IABSE-AIPC-IVBH, ETH-Hönggerberg, Zürich, pp. 1-28, February 1991. (Reprints available).

\*This is one of the documents of a series of publications, prepared by individual authors but discussed within the Joint Committee on Structural Safety (JCSS), in particular within its Working Party.

The papers are referred to as "Working Documents" since they generally give information on the state of development of certain concepts or subjects, rather than giving approved guidelines.

This paper gives a description of the basic elements of the decision theory published by von Neumann and Morgenstern in 1943. Emphasis is put on discussing the influence of the uncertain evaluation of the probabilities and the utilities to be used as input to the decision model. The important problem of making rational risk aversion modeling is considered. The paper claims that the decision theory is applicable as a formal basis for structural design decisions provided the decision maker accepts some few codified constraints. The purpose of these constraints is to ensure public consensus about the choice of the more severe socio-economical costs of adverse behavior that must be considered in the design problem. Specific examples deal with utility loss considerations and risk aversion modeling in structural engineering.

DITLEVSEN, O. and H. GLUVER: \*Parameter estimation and statistical uncertainty in random field representations of soil strengths. Proc. of ICASP6 Sixth international conference on applications of statistics and probability in civil engineering (eds. L. Esteva and S.E. Ruiz), Mexico City, June 1991. Publishers: CERRA (International Association for Civil Engineering Reliability and Risk Analysis), pp. 693-704, 1991. (Reprints available).

\*Recent reliability evaluations of large foundations on saturated clay tills motivate an

elaborated random field model for the variation of the "true" undrained shear strength over the relevant soil body upon consolidation. The generic set of candidate functions for the interpolation between the given cone tip resistance profiles (CPT profiles) is of operational reasons taken to be the set of sample functions of a homogeneous, horizontally isotropic and vertically Markovian logarithmic normal random field. Its probability densities are defined by four parameters (mean, variance, and two correlation parameters) modeled to be Bayesian random variables for which a posterior distribution is obtained by use of the given CPT profiles. Conditioning on the CPT profiles gives an inhomogeneous random field which is compared to measured vane shear strengths at given points of the soil body. Probabilistic models for the uncertainties of each of the two independent measuring methods tied together by an assumption of proportionality between the "true" cone tip resistance and the "true" vane shear strength lead to the operationally simplest possible statistical model for making the comparison. This model introduces three more Bayesian random variables, the proportionality factor, the variance reduction factor, and the variance of the vane test measuring error, of which the two first are applied on the inhomogeneous CPT field in order to transform it into the "true" in situ shear strength field. Finally, a non-standard interpretation of the triaxial compression test gives the information needed to define a random transformation of the "true" in situ shear strength field into the "true" shear strength field as it is assumed to exist upon the termination of the consolidation from the weight of the structure. It is concluded that a manageable random field model is available for the undrained shear strength embracing the relevant soil strength data in terms of some few Bayesian random variables that can be included in practicable automatic foundation reliability computations.

DITLEVSEN, O., se også ARNBJERG-NIELSEN, T. og O. DITLEVSEN

DYRBYE, C.: Opgaver i bygningsdynamik, 6. udg. (\*Problems in Structural Dynamics. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 119, 1990. 120 s. Kr. 35,- excl. moms.

Opgavesamlingen indeholder øvelses- og eksamensopgaver i Bygningsdynamik.

\*The collection of problems consists of training- and examination problems in Structural Dynamics.

DYRBYE, C.: Jordskælvsteknik. (\*Earthquake Engineering. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 125, 1991. 88 s. Kr. 30,- excl. moms.

Begreber vedrørende jordskælv introduceres i forbindelse med den pladetektoniske model og ledsagefænomener som fluidisering og tsunami.

En metode til computer simulation af grundbevægelse er vist. Efter introduktion af responspektre gennemgås respons af systemer med flere frihedsgrader og herunder kobling mellem translation og torsion. For behandling af ikke-linéært respons indføres begrebet duktilitet.

Konstruktive forhold behandles i store træk med særligt hensyn til regularitet. Muligheder for at isolere bygninger mod jordskælv nævnes. Vedrørende normer omtales ISO 3010 og Eurocode 8.

\*Concepts related to earthquakes are introduced in connection with the plate-tectonic model and attendant phenomena as soil liquefaction and tsunamis.

A method for computer simulation of ground accelerations is shown. Response spectra are defined and used in connection with response calculations of MDOF systems. Coupling between translational and rotational motions is treated. The idea of ductility is introduced in connection with non-linear response.

The importance of structural regularity is emphasized. The possibilities of using base-isolation as a measure of reducing the effects of seismic actions are mentioned. A section about codes is limited to ISO 3010 and Eurocode 8.

DYRBYE, C., se også TRABERG S. og C. DYRBYE

ENQUIST, BERTIL, se RIBERHOLT, H., BERTIL ENQUIST, PER JOHAN GUSTAFSSON og RALPH BO JENSEN

FEDDERSEN, B., D. HOLKMANN OLSEN og M.P. NIELSEN: Besvarelser til opgaver i styrkeberegning af beton og jernbeton. 2. udgave. (\*Answers to Problems in Limit Analysis and Concrete Plasticity 2nd ed. In Danish). Afdelingen for Bærende Konstruktioner. Serie I, nr. 101, 1991. 188 s.

Den foreliggende 2. udgave af "Besvarelser til opgaver i styrkeberegning af beton og jernbeton" indeholder løsningerne til opgaverne i "Opgaver i styrkeberegning af beton og jernbeton", udgivet som forelæsningsnotat nr. F 117 ved Afdelingen for Bærende Konstruktioner, Danmarks Tekniske Højskole.

\*The present 2nd edition of "Answers to Problems in Limit Analysis and Concrete Plasticity" contains the solutions to the exercises in "Exercises in Reinforced Concrete Plasticity". This note No. F 117 is edited as lecture note at the Department of Structural Engineering, Technical University of Denmark.

GANWEI, CHEN, BENT S. ANDREASEN og M.P. NIELSEN: \*Membrane Action Tests of Reinforced Concrete Square Slabs. (Forsøg vedr. membranvirkning i armerede betonplader). Afdelingen for Bærende Konstruktioner. Serie R, nr. 273, 1991. 94 s. Gratis.

Denne rapport beskriver 22 forsøg vedr. kuppelvirkning i armerede betonplader. Pladerne havde såkaldt normal hindring af randenes flytning i vandret plan. Belastningen var to enkeltkræfter.

Forsøgsidéen, prøvelegemerne, materialerne, forsøgsopstillingen, måleinstrumenterne og forsøgsresultaterne beskrives i detaljer. Endelig sammenlignes forsøgsresultaterne med de teoretiske, plastiske løsninger.

\*This report describes compressive membrane action tests of 22 reinforced concrete square slabs with normal horizontal restraint and subjected to two concentrated loads.

The test design, the test specimens, the materials, the test set-up, the measuring instruments and the test results are reported in detail. The test results are finally compared with the theoretical plastic solutions.



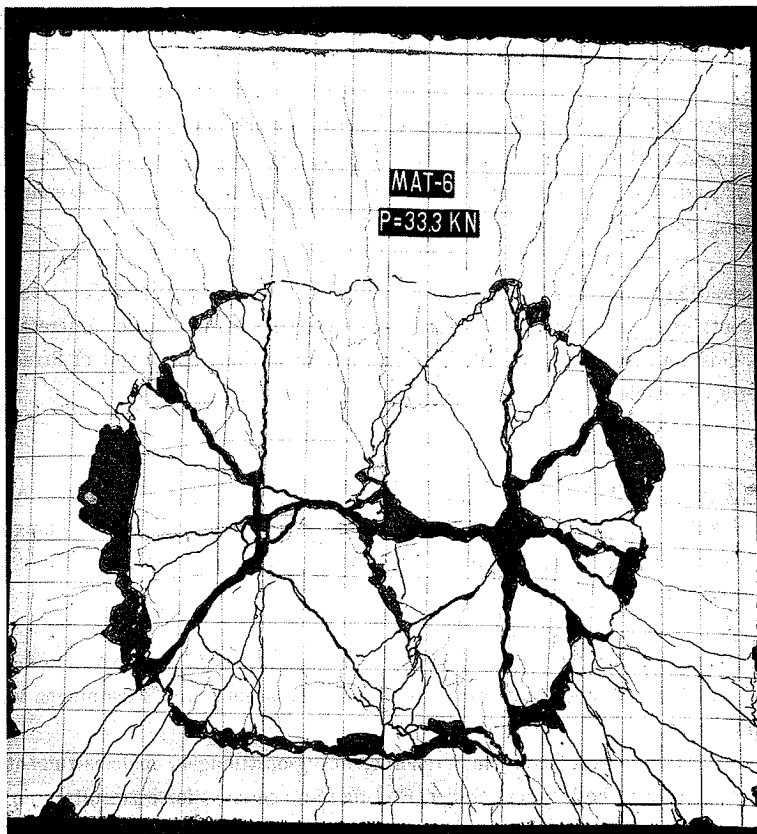
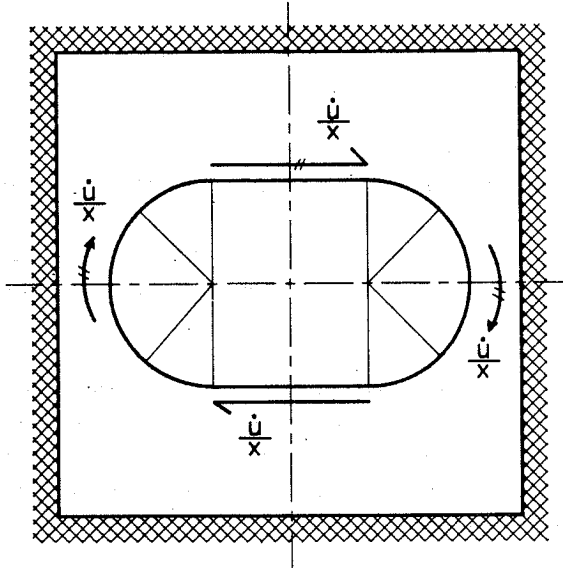


Foto af oversiden af en af pladerne efter afprøvning.

\*Photo of the top of a tested slab.

Ref.: Ganwei, Chen, Bent S. Andreasen og M.P. Nielsen: Membrane action tests of reinforced concrete square slabs (s. 15).



Kvadratisk plade med vandret fastholdelse langs alle fire sider og påvirket af to enkeltkræfter.

\*Square slab with horizontal restraints along all edges and subjected to two concentrated loads.

Ref.: Ganwei, Chen, Bent S. Andreasen og M.P. Nielsen: Membrane action tests of reinforced concrete square slabs. (s.15).

GLAVIND, M. and H. STANG: \*Evaluation of the Complete Compressive Stress–Strain Curve for High Strength Concrete. (Bestemmelse af den Fuldstændige Tryk–arbejdskurve for Højstyrkebeton). In: Fracture Processes in Concrete, Rock and Ceramics. Eds. J.G.M. van Mier, J.G. Rots and A. Bakker. Spon, London, 1991, pp. 749–759.

\*This paper deals with an investigation and discussion of compressive stress–strain curves for high–strength concrete, and the applicability of the curves in a structural element calculation. The stress–strain curves are obtained in a closed loop testing machine, where different combinations of axial and circumferential deformations are used as the

feed-back signal.

GLAVIND, M. AND H. STANG: \*A Geometrical Packing Model as a Basis for Composing Cement Paste Containing Clay for High Strength Concrete. (En Geometrisk Pakningsmodel som Grundlag for Sammensætning af Cementpasta med Ler til Højstyrkebeton). In: Brittle Matrix Composites 3. Eds. A.M. Brandt and I.H. Marshall. Elsevier Science Publishers, Barking, 1991, pp. 508-518.

\*In order to obtain a more ductile high strength concrete the cement paste is modified by adding clay. A geometrical packing model is used in determining the composition of the cement paste containing clay, silica fume and cement. The theoretically calculated packing densities show good correlation with the experimentally established packing densities. Some of the most promising compositions of microfiller and cement are tested in high strength concrete.

GLUVER, H., se DITLEVSEN, O. og H. GLUVER

GUSTAFSSON, PER JOHAN, se RIBERHOLT, H., BERTIL ENQUIST, PER JOHAN GUSTAFSSON og RALPH BO JENSEN

ILIC, ALEKSANDAR: Konstruktionspatologi. (\*Construction Pathology. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 267, 1991. 168 s. Gratis. /Lic./.

Antallet af skadede betonkonstruktioner stiger desværre dag for dag, og andre bygværker synes at støtte denne konstatering.

Det er i samfundets interesse, gennem præventivt arbejde, at mindske antallet af skadede bygværker, og at de, der er skadede, bringes - økonomisk gunstigt - i en forsvarlig stand. Medicinen lærer os, at rationel bekæmpelse af sygdomme består af tre komponenter: Patologi - Diagnose - Terapi.

I første afsnit af nærværende afhandling vises, hvordan opdeling og metoder i patologi, anvendt i medicinen, uden større vanskeligheder kan anvendes i teknikken.

Brobygning er en af de ældste byggekundskaber mennesket har opbygget, og i dag med den tekniske udvikling og det stigende antal broer stilles der store krav til ingeniørens viden og uddannelse.

I andet afsnit gennemgås brobygning i et historisk perspektiv.

I tredje afsnit findes detaljerede analyser af syv udvalgte betonbroer.

Her anvendes medicinens metodik og i videst muligt omfang stilles diagnose.

Ønsker vi at vende udviklingen i antallet af patologiske forandringer og de stigende udgifter til udbedring af disse, må vi i langt højere grad optimere konstruktionerne gennem kvalitative og kvantitative analyser.

Efterfølgende vedligehold kan optimeres teknisk og økonomisk gennem større viden og dens udbredelse.

Fjerde afsnit indeholder nogle metoder til minimisering af patologiske forandringer.

\*It is a sad fact that the number of damaged concrete bridges increases every day, and other structures seem to follow this trend.

It must be a social aim to reduce, by preventive efforts, the number of damaged structures, and to restore those already damaged to a healthy condition in terms of sound economics. We learn from medicine that rational combating of disease consists of three elements: Pathology – Diagnosis – Therapy.

The first chapter of this thesis demonstrates how the classification and methods of pathology as applied in medicine can be applied in technology with equal benefit.

Bridge building is one of mankind's oldest building proficiencies, and developments in technology and the increasing number of bridges make high demands on present-day engineering skills and experience.

The second chapter describes bridge building in a historical perspective.

Seven bridges have been selected for detailed analysis in the third chapter.

Medical methodology is applied throughout in an extensive diagnosing effort.

Based on the wish for a reversal of the growing trends of pathological changes and the increasing costs of repairs we must sophisticate constructional solutions through qualitative and quantitative analyses.

Maintenance is subject to technical and financial optimisation through increased knowledge and the dissemination of knowledge.

The fourth chapter contains methods on reducing pathological changes to a minimum.

JENSEN, RALPH BO, se RIBERHOLT, H., BERTIL ENQUIST, PER JOHAN GUSTAFSSON og RALPH BO JENSEN

JÖNSSON, J., S. KRENK and L. DAMKILDE: \*The Semi-Loof Element for plate instability. Engineering Mechanics Papers, R9122, Department of Building Technology and Structural Engineering, The University of Aalborg, 1991, pp. 13. /%/.

\*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. In the report it is demonstrated that the use of the tangent plane representation in the geometric stiffness matrix is far superior to the alternative, that seems to be the common form at present.

KARLSHØJ, JAN: Notat om CAD-databaser – en beskrivelse med udgangspunkt i databaser fra Euclid-IS og AutoCAD. (\*CAD databases – a description of the databases from Euclid-IS and AutoCAD. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 121, 1991. 39 s. Kr. 20,- excl. moms.

Notatet beskriver den overordnede struktur af to principielt forskellige CAD-databaser fra dels et solid modelling- og et tegnesystem.

Databaserne vurderes ud fra mulighederne for at organisere et projektmateriale, omfang og beskrivelse af entiteter samt den interne datastruktur. Endvidere diskuteres databasens indflydelse på CAD-systemets modellerings- og editeringsfaciliteter.

\*The report describes the main structure of two fundamentally different CAD-database concepts originating from either a solid-modelling system or a drafting system.

The databases are evaluated from the possibilities to organize project documents, number and description of entities and the internal datastructure. Furthermore, we discuss the influence from the database-design on the CAD-systems modelling- and editing-facilities.

KARLSHØJ, JAN: Point – en beskrivelse af et tegningsbaseret projekteringsværktøj.  
(\*Point – a description of a drawingbases system for building design. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 122, 1991. 86 s. Kr. 30,— excl. moms.

Notatet beskriver principperne i CAD-projektering med byggeapplikationen Point, der er en overbygning til AutoCAD. Hovedvægten er lagt på projektorganisering og struktur i tegningsmaterialet.

Der opstilles forslag til tegnings- og projektorganisering tilpasset AutoCADs og Points faciliteter. Begrænsninger i den traditionelle opdeling af CAD-tegninger med lag-teknik beskrives, og produktmodel begrebet introduceres.

\*This report describes the principle of CAD-design with the building application Point, which is an extension to AutoCAD. Projectmanagement and structure of the drawing material are the main topics.

Suggestion to drawing- and projectmanagement which fit with the facilities in AutoCAD and Point is proposed. Limitations in the traditional layer-structure of CAD-drawings are described, and the idea of productmodel is introduced.

KARLSHØJ, JAN: Produktinformation opdelt efter Form, Funktion og Struktur.  
(\*Product information divided after Shape, Function and Structure. In Danish). Afdelingen for Bærende Konstruktioner. Serie I, nr.104, 1991. 24 s.

Notatet vurderer et forslag til en produktmodel fra Teknologi-Rådets projekt "Fremskaffelse af digital produktinformation". Der gives en kort redegørelse for brugen af produktinformation i byggeindustrien. Den foreslåede produktmodel sættes i relation til eksisterende og kommende klassifikations- og udvekslingsstandarder.

\*The report evaluates a proposal to a product model from "Teknologi-Rådets" project "Establishment of digital product information". A short introduction to the use of product information in the building industry is given. The proposed product model is evaluated in relation to existing and expected classification and exchange standards.

KRENCHEL, H. og ERIK STOKLUND LARSEN: \*Durability of FRC-Materials. (Fiberbetons og Fibercements Bestandighed). Afdelingen for Bærende Konstruktioner. Serie I, nr. 100, 1991. 11 s.

\*One of the best and most direct ways of evaluating the durability of a fibre reinforced brittle matrix material is to determine, over the years, the development in the fracture energy of the composite, either in uniaxial tension or in bending, bending tests being the simplest.

Eight different series of frc-material have been examined in this way covering cement and concrete materials reinforced with steel and polypropylene fibres, with different types of alkali-resistant glass fibres and with two types of natural cellulose.

The conclusion is that cementitious materials reinforced with steel fibres and polypropylene become stronger and tougher over the years, even when exposed to harsh climatic conditions, whereas frc-materials based on glass fibres or cellulose become more and more brittle, so that practically no fibre effect is left in the material after some five to eight years of outdoor exposure.

En af de bedste og mest direkte prøvemetoder til bedømmelse af et frc-materiales bestandighed er at måle udviklingen gennem årene i kompositmaterialets brudenergi, bestemt enten ved énaksede træk eller ved bøjningsforsøg, hvor sidstnævnte forsøgstype er den enkleste at udføre.

Der er undersøgt otte forskellige serier frc-materiale på denne måde dækkende cement- og betonmaterialer armeret med stål- og polypropylenfibre, forskellige typer ar-glas samt to typer cellulosefibre.

Konklusionen af undersøgelseerne er, at frc-materialer armeret med stål- og med polypropylenfibre samt kombinationer af disse bliver stærkere og sejere med årene selv under meget barske klimatiske forhold, hvorimod cementbundne materialer armeret med glasfibre eller cellulose bliver stadig mere skrøbelige med årene. Der er således praktisk taget

ingen fibervirkning at spore i disse sidstnævnte materialer efter fem til otte års påvirkning i normalt udendørs klima.

KRENK, S. and L. DAMKILDE: \*Deformation and Stiffness of I-beam Joints. In proceedings of 1991 ECCS, Nordic Steel Colloquium. European Convention for Structural Steelwork Annual Meeting, pp. 325–336, 1991.

\*The stiffness of thin-walled frames, and thereby their stability, depends on the details of the joints as well as the support conditions. A theory is presented for the transmission and restraint of warping in four types of I-beam joints. The theory is based on a combination of warping and local cross-section distortion. For each joint type the results are in the form of a continuity condition and a stiffness contribution. This format is compatible with a finite element representation of frames by thin-walled beam elements. The effect of joint type on the stability load of frames is illustrated by examples.

KRENK, S. and L. DAMKILDE: \*Warping of Joints in I-Beam assemblages. Journal of Engineering Mechanics, Vol. 117, No. 11, November, 1991, pp. 2457–2474. (Reprints available).

\*A simple theory is developed for the coupled warping and cross-sectional distortion at joints between thin-walled I-beams. Continuity of the joined flanges and the local character of the cross-sectional distortion permit the distortion deformation to be expressed in terms of the warping parameters of the two beams at the joint. Four types of joints are treated. The unstiffened joint has two independent warping parameters, the two partially stiffened joints each have a single warping parameter, while the fully stiffened joint prevents warping. The distortion mode acts as a local spring stiffness. The formulation is fully compatible with classical thin-walled beam theory, and detailed three-dimensional finite element analyses demonstrate high accuracy of the theory.

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



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

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

LARSEN, ERIK STOKLUND, se KRENCHER, H. og ERIK STOKLUND LARSEN

LARSEN, H.J., se RIBERHOLT, H og H.J. LARSEN

MORSING, NIELS, se RIBERHOLT, H. og NIELS MORSING

MØLLMANN, H.: Beregning af Hængetagskonstruktioner (\*Analysis of hanging roofs. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 127, 1991. 80 s. Kr. 26,— excl. moms.

I notatet udvikles metoder til beregning af kabelkonstruktioner, især med henblik på hængetage. Der behandles hovedsagelig statiske problemer, men også enkelte dynamiske problemer (bestemmelse af egenfrekvenser).

I det første hovedafsnit gennemgås metoder, hvor kabelsystemet behandles som et ækvivalent kontinuert system. Der udledes formler til beregning af enkeltkabler (barduner), kabeldragere og kabelnet.

Det andet hovedafsnit drejer sig om en edb-orienteret iterativ beregningsmetode, hvor kabelkonstruktionen behandles som et diskret system (elementmetode for stangsystem med endelige flytninger).

\*This lecture note deals with methods of analysis for cable structures (with particular reference to hanging roofs). The problems treated are mainly statical, but a few dynamic problems are also included (determination of natural frequencies).

The first main section of the note deals with methods, in which the cable system is treated as an equivalent continuous system. Formulae are derived for the calculation of single cables (stays), cable trusses, and cable nets.

The second main section deals with a computer-oriented iterative method of analysis, in which the cable structure is treated as a discrete system (a finite element method for

a system of straight bars connected at frictionless hinges and undergoing finite displacements).

MÖLLMANN, H.: Beregning af skalkonstruktioner. (\*Analysis of shell structures. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 130, 1991. 148 s. Kr. 45,- excl. moms.

Notatet giver en introduktion til beregningsmetoder for skalkonstruktioner. I kapitel 1 gennemgås skalteoriens styrende ligninger. Kapitel 2 drejer sig om membranteori såvel for vilkårlige skaller (spændingsfunktion) som for omdrejningskaller. Kapitel 3 behandler rotationssymmetrisk bøjning af omdrejningskaller, idet der især lægges vægt på tilnærmelsesmetoder. Endelig drejer kapitel 4 sig om usymmetrisk bøjning af omdrejningskaller pga. belastninger af typen "vindlast".

\*This lecture note gives an introduction to the calculation of shell structures. Chapter 1 presents a brief derivation of the governing equations of shell theory. Chapter 2 deals with the membrane theory both for shells of arbitrary shape (in terms of a stress function) and for shells of revolution. Chapter 3 is devoted to axisymmetric bending of shells of revolution with particular emphasis on approximate methods. The final chapter 4 deals with bending of shells of revolution subjected to an unsymmetric load of the type "wind load".

NIELSEN, KARSTEN: Analyse af skråstagsbroers egenvægtstilstand. (\*Analysis of Deadload-Condition for Cable-Stayed Bridges. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 277, 1991. 58 s. Gratis.

Notatet omhandler beregning af endelige egenvægtstilstande for skråstagsbroer. Ved i egenvægtstilstanden at foreskrive snitkræfter svarende til systemets statiske ubestemt-  
hed kan snitkræfterne i den øvrige del af konstruktionen bestemmes ved simple ligevægtsligninger. Resultatet opfylder både krav til snitkraftfordelingen i brosystemet og slutgeometri i den endelige egenvægtstilstand.

Ligevægtsligningerne for et plant brosystem opstilles.

Midlertidige montagefaser og initiale kabel-opspændinger kan ud fra den endelige egenvægtstilstand bestemmes vha. "backward-metoden". Snitkræfter fra den endelige egenvægtstilstand påføres montagefasesystemet modsatrettede. Derved fremkommer snitkraftfordelingen samt konstruktionens geometri under hele montageforløbet.

Endelig beskrives Turbo-Pascal-programmet "Stagprogram", som beregner egenvægtstilstande for skrånstagsbroer ud fra foreskrevne snitkræfter i den endelige egenvægtstilstand.

\*The report describes the calculation of final deadload-conditions for cable-stayed bridges. By prescribing girder- and pylon-forces in the final deadload-condition, corresponding to the indefiniteness of the static system, cable-forces and remaining girder- and pylon-forces can be determined. The result fulfils conditions to distribution of forces and geometry in the final deadload-condition.

Equilibrium-conditions for a plane bridge structure are formulated.

Temporary conditions under construction and initial cable-forces can be determined from the final deadload-condition by the "backward-method". Forces from the final deadload-condition will be applied to the temporary statical system in the opposite direction. So the distribution of forces and geometry under all temporary conditions can be determined.

Finally, the report describes the Turbo-Pascal-program named "Stagprogram" which calculates the deadload-condition from prescribed forces.

NIELSEN, LEIF OTTO: \*Continuummechanical Lagrangian finite elements. (Kontinuummekaniske Lagrangeske finite elementer). Afdelingen for Bærende Konstruktioner. Serie R, nr. 278, 1991. 50 s. Gratis.

\*The theory, construction and use of n-dimensional cube and simplex finite elements of Lagrange type with structural type generality are described. Because the elements can model several forms for continua, e.g. 0-, 1-, 2- and 3-dimensional continua, and several continuum mechanical theories, e.g. Timoshenko-beams, plane stress and heat conduction, the elements are characterized as continuummechanical. The arbitrary approximating order of the elements is a must in connection with their use in p-version finite element software.

Teorien, opbygningen og brugen af  $n$ -dimensionale terning og simplex finite elementer af Lagrange type med konstruktionstypegeneralitet er beskrevet. Fordi elementerne kan modellere adskillige former for kontinua, f.eks. 0-, 1-, 2- og 3-dimensionale kontinua, og adskillige kontinuummekaniske teorier, f.eks. Timoshenko-bjælker, plan spændingstilstand og varmeledning, karakteriseres elementerne som kontinuummekaniske. Elementernes vilkårlige approksimationsorden er en nødvendighed i forbindelse med deres anvendelse i  $p$ -version elementmetodeprogrammer.

NIELSEN, LEIF OTTO: Pladers statik, 3. udgave. (\*Plate bending. 3rd. ed. In Danish).

Afdelingen for Bærende Konstruktioner. Serie F, nr. 128, 1991. 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.: \*Concrete Beam Shear Design according to Eurocode 2. (Bestemmelse af forskydningsarmering i bjælker efter Eurocode 2). Southeast University, Nanjing, China, 1991, pp. 1949–1954.

\*The paper gives a review of calculation methods for concrete beam shear design according to the new common concrete code in EEC, Eurocode 2. In this code the plastic theory (the diagonal compression field theory) is allowed. This method is described in the paper. The method can be extended to cover the case of bending with external normal force. How this is done is also shown in the paper.

Artiklen giver en oversigt over beregningsmetoder for bestemmelse af forskydningsarmring i bjælker efter den nye fælleseuropæiske betonnorm, Eurocode 2. I denne norm tillades plasticitetsteorien anvendt (diagonaltrykmetoden). Denne metode beskrives i artiklen. Metoden kan let udstrækkes til at gælde bøjning med normalkraft. Hvorledes dette kan ske vises også i artiklen.

NIELSEN, M.P.: \*Eurocode 2, part 1B. Precast Concrete Elements and Structures. (Eurocode 2, part 1B. Betonelementbyggeri). International Symposium on Industrialized Housing. Seoul, Korea, May 23–25, 1991. 13 pp.

\*The paper gives a short review of Eurocode 2, part 1B, covering precast concrete elements and structures. First, the Eurocode system is described in general terms and especially the Eurocode 2, which is closely connected to part 1B. The paper describes calculation methods for special elements, joints and provisions for preventing progressive collapse.

Artiklen giver en kort oversigt over Eurocode 2, part 1B, som dækker betonelementbyggeri. Først beskrives Eurocode systemet generelt og specielt Eurocode 2, som part 1B knytter sig til. Artiklen beskriver beregningsmetoder for specielle betonelementer, fuger og støbeskel og regler for forhindring af progressiv kollaps.

NIELSEN, M.P., se også ANDREASEN, BENT STEEN og M.P. NIELSEN

NIELSEN, M.P., se også FEDDERSEN, B., D. HOLKMANN OLSEN og M.P. NIELSEN

NIELSEN, M.P., se også GANWEL, CHEN, BENT S. ANDREASEN og M.P. NIELSEN

OLSEN, D. HOLKMANN, se også FEDDERSEN, B., D. HOLKMANN OLSEN og M.P. NIELSEN

PEDERSEN, N. THOUGÅRD and H. AGERSKOV: \*Fatigue life prediction of offshore steel structures under stochastic loading. (Udmattelseslevetiden af offshore stålkonstruktioner ved stokastisk last). Afdelingen for Bærende Konstruktioner. Serie R, nr. 274, 1991. 112 s. Gratis.

\*The fatigue life of offshore steel structures under stochastic loading is studied in the present investigation. Of special interest is the problem of fatigue damage accumulation and in this connection, a comparison between experimental results and results obtained using current codes and specifications.

Fatigue test series with various types of stochastic loading that are realistic in relation to offshore structures have been carried through. Four different load spectra with irregularity factors ranging from  $\sim 0.70$  to  $1.00$  have been applied. The experimental investigation comprises both test series on full-scale tubular joints and test series on smaller welded test specimens. The materials that have been used until now have been ordinary offshore structure steels, with a yield stress of  $f_y \approx 360 - 410$  MPa.

The test series that have been carried through show a significant difference between constant amplitude and variable amplitude fatigue test results. For the welded plate test specimens, approx. 100 fatigue tests have been carried out, and the values of the Miner sum that were obtained in the variable amplitude test series generally vary in the range  $1/3$  to  $2/3$ . For the full-scale tubular joints, the number of test results is at present too limited to draw final conclusions. However, the results obtained until now indicate a value of the Miner sum of  $M \sim 0.8$  for the variable amplitude tests.

I det aktuelle projekt undersøges udmattelseslevetiden af offshore stålkonstruktioner under påvirkning af stokastisk last. Af særlig interesse er udmattelseskade akkumulering, og i denne forbindelse en sammenligning mellem eksperimentelle resultater og resultater opnået ved anvendelse af gældende normer og standarder.

Der er i projektet gennemført udmattelsesforsøgsserier med forskellige typer stokastisk last, som er realistiske i relation til offshore konstruktioner. Der er anvendt fire forskellige lastspektre med irregularitetsfaktorer fra  $\sim 0.70$  til  $\sim 1.00$ . Der er gennemført forsøgsserier med såvel fuldskala rørknudesamlinger som mindre svejste pladeprøvelegemer. Materialerne til prøvelegemerne har været stål kvaliteter, som normalt anvendes i offshore stålkonstruktioner i dag, med en flydespænding på  $f_y \approx 360 - 410$  MPa.

De hidtil gennemførte forsøgsserier viser en betydelig forskel mellem de resultater, der er opnået i forsøgene med konstant amplitude last, og de tilsvarende resultater fra forsøgene med stokastisk last. For de svejste pladeprøvelegemer er gennemført ca. 100 udmattelsesforsøg, og de værdier af Miner summen, der blev opnået i forsøgsserierne med stokastisk last, ligger generelt i intervallet  $1/3 - 2/3$ . For fuldskala rørknudesamlingerne er antallet af udmattelsesforsøg, der er gennemført på nuværende tidspunkt, for begrænset til, at der kan udledes tilsvarende generelle konklusioner. I de hidtil gennemførte forsøg på rørknudesamlingerne med stokastisk last er opnået værdier af Miner summen på  $M \sim 0.8$ .

PEDERSEN, N. THOUGÅRD and H. AGERSKOV: \*Fatigue Damage Accumulation in Offshore Tubular Structures under Stochastic Loading. (Skadesakkumulering i offshore rørkonstruktioner udsat for stokastisk last). Proceedings of the International Symposium on Tubular Structures, Delft, June, 1991, pp. 269–280. (Reprints available).

\*The fatigue life of offshore tubular structures under stochastic loading is studied. Fatigue test series with various types of stochastic loading that are realistic in relation to offshore structures have been carried through. The experimental investigation comprises both test series on full-scale tubular joints and test series on smaller welded test specimens.

The test series that have been carried through until now show a significant difference between constant amplitude and variable amplitude fatigue test results. The values of the Miner sum that were obtained in the variable amplitude test series on the welded plate test specimens, generally vary in the range  $1/3$  to  $2/3$ . For the full-scale tubular joints, the number of test results is at present too limited to draw final conclusions. However, the results obtained until now indicate a value of the Miner sum of  $M \sim 0.8$  for the variable amplitude tests.

PEDERSEN, N. THOUGÅRD, se også AGERSKOV H. og N. THOUGÅRD PEDERSEN

PETERSEN, P., S. KRENK og L. DAMKILDE: Stabilitet af rammer af tyndpladeprofiler. (\*Stability of thin-walled frames. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 265, 1991. 76 s. Gratis.

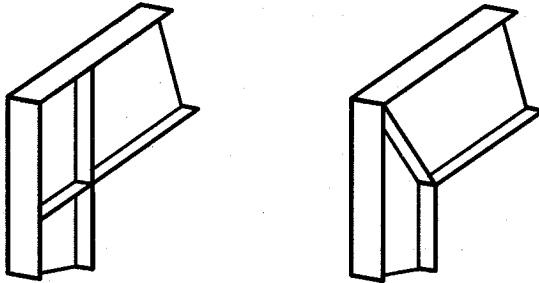
Rapporten omhandler teorien for beregning af stabilitetslasten for plane rammer opbygget af tyndpladeprofiler, og der opstilles modeller for overførsel af hvælving ved samlingerne. Bjælkernes statiske virkemåde beregnes som for udeformede tværsnit, selv om der lokalt kan forekomme tværsnitsdeformationer ved samlingerne. Idet tværsnittet kan hvælve, benyttes Vlasov's bjælketeori til formulering af elementstivhedsmatricerne. For samlingerne angives overgangsbetingelserne og bidrag til systemstivhedsmatricen. Stabilitetsproblemet behandles rumligt under antagelse af lineær variation i normalkraft og kvadratisk variation i moment gennem et bjælkeelement. Der benyttes kubiske formfunktioner, således at stabilitetsproblemet optræder som et lineært egenværdiproblem. En række klassiske problemer behandles for at verificere det udviklede edb-program.

\*The report deals with stability analysis of plane, thin-walled frames and models for transmission of warping through the connections. The statical behavior of the beam elements are based on undistorted cross-sections even though locally the connections will give distortions. Due to the warping we employ the beam theory of Vlasov in the formulation of the stiffness and the geometric matrices. We establish the boundary conditions for the connections and their contributions to the global stiffness matrix. The stability program is 3-dimensional, and we assume linear respectively quadratic variation of the normal force and the bending moment. Cubic shape functions are used, and therefore the stability problem results in a linear eigenvalue problem. A number of classical problems are treated in order to verify the computer program.

PHILIPSEN, CLAUS: Bjælkekonstruktioner, Bærende Konstruktioner Grundkursus 1. (\*Beam Structures, Basic Structural Analysis 1. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 124, 1991. 147 s + appendiks 17 s. Kr. 45,- excl. moms.

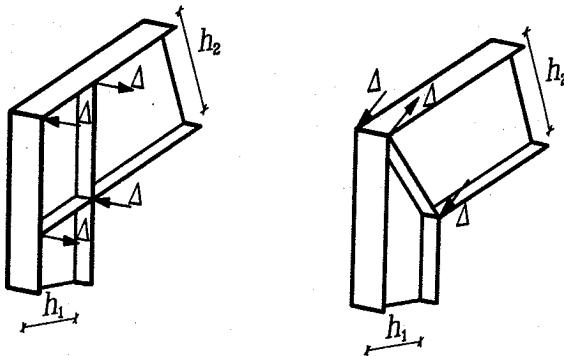
Det virtuelle arbejdes princip for en partikel, for et stift legeme og for deformerbare bjælker introduceres. Metoden anvendes herefter til bestemmelse af reaktioner, snitkræfter





Hjørnesamlinger i rammer. Kassesamling og pladesamling.

\*Corner connections in frames. Box connection and plate connection.



Globale hvælningsparametre i samlinger.

\*Global warping parameters in connections.

Ref.: Petersen, Peter, Steen Krenk og Lars Damkilde: Stabilitet af rammer af tyndplade-  
profiler. (s. 31).

og deformationer i bjælkekonstruktioner.

Kraftmetoden, baseret på det virtuelle arbejdes princip, anvendes til beregning af statisk ubestemte bjælkekonstruktioner. Bestemmelse af snitkræfter og deformationer i bjælkekonstruktioner, hvor materialet er lineært-elastic/idealt plastisk, og hvor der derfor kan forekomme flydeled, gennemgås.

Metoder til spændingsbestemmelse i bjælker beskrives.

Et afsnit med øvelsesopgaver afslutter notatet.

\*The principle of virtual work for a particle, for a rigid body, and for deformable beams is introduced.

Hereafter the method is used for the determination of reactions, internal forces and deformations of beam structures.

The force-method based on the principle of virtual work is used for the calculation of statically indeterminate beam structures.

The determination of internal forces and deformations of beam structures, where the material is linear-elastic/ideal-plastic and where consequently plastic hinges may occur, is analysed.

Methods for the determination of stresses in beams are described.

An appendix with exercises completes the book.

**PHILIPSEN, CLAUD:** Matematiske metoder i konstruktionsmekanik – Differentialligninger for bjælker (Bjælker, søjler og tove). (\*Mathematical methods in mechanics. Differential equations for beams (Beams, columns and cables). In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 131, 1991. 55 s. Kr. 22,- excl. moms.

Efter en kort introduktion af statikkens grundbegreber opstilles systemer af differentialligninger til bestemmelse af snitkræfter i bjælker i udeformeret tilstand, i deformeret tilstand og for bjælker, der er påvirket af en dynamisk belastning. Der indføres en geometrisk beskrivelse af bjælkens deformationstilstand, og som fysisk betingelse anvendes Hookes lov.

Bjælkerne regnes påvirket af mekanisk last og af temperaturændringer.

Søjler og tove behandles som specielle bjælkeproblemer.

\*After a short introduction of the fundamental concepts of statics, systems of differential equations are formulated for the determination of internal forces in beams in the undeformed condition, in the deformed condition and for the dynamically loaded condition.

A geometrical description of the deformation of beams is introduced. As physical condition, Hooke's law is applied.

The beams are calculated for mechanical load and for change of temperature. Columns and cables are treated as special beam problems.

RESUMÉOVERSIGT 1990: "Summaries of Papers 1990". Afdelingen for Bærende Konstruktioner. Serie R, nr. 268, 1991. 63 s. Gratis.

Resumeer af 39 videnskabelige publikationer m.v., af 1 rapport over rekvirerede undersøgelser og af 5 eksamensarbejder.

\*Summaries in Danish and English of 39 scientific papers etc., of 1 report on contract work, and of 5 final year projects.

RIBERHOLT, H.: Limtræ af dansk træ, HQL-planker, Del 2. (\*Glued laminated timber of Danish timber, HQL-planks. Part 2. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 279, 1991. 19 s. Gratis.

Der er givet en redegørelse for, at limtræ produceret af HQL-planker må forventes at kunne klassificeres i styrkeklasserne C40 efter EN TC 124,207 og L40 efter DS 413.

Der er endvidere udført forsøg til fastlæggelse af bøjningsstyrken af fingerskarringer i HQL-planker fremstillet af Palsgaard Træ A/S. Disse fremstilles af træ, hvor der stilles særligt strenge krav til årringsbredden, hvorved densiteten og dermed veddets styrke bliver særlig høj. Dette skulle muliggøre særligt stærke fingerskarringer. I betragtning af de store tværsnitsdimensioner 58 × 295 mm synes dette at være opnået. Det må forventes, at for lameller med tykkelser op til ca. 45 mm vil det være muligt at opfylde styrkekravene til fingerskarringerne for de to ovennævnte styrkeklasser.

\*It is argued that glued laminated timber produced from HQL-lumber can be classified

in the strength classes C40 according to EN TC 124.207 and L40 according to DS 413.

Further, tests have been performed to determine the bending strength of finger joints in HQL-lumber produced by Palsgaard Træ A/S. HQL-lumber is manufactured from wood which has been graded to rules with a very strict requirement to the annual ring width. This should secure a high density and strength of the wood and so result in especially strong finger joints. In view of the large cross sections  $58 \times 295$  mm this appears to have been achieved. It is expected that for laminations of a thickness up to approximately 45 mm it will be possible to fulfil the strength requirements to the finger joints for the two above mentioned strength classes.

RIBERHOLT, H.: Tækonstruktioner. Eksempler. (\*Timber Structures. Examples. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 120, 1991. 155 s. Kr. 45,- excl. moms.

Der er gennemregnet 24 eksempler, der skulle illustrere de statiske beregninger for samt design af nogle typiske bærende trækonstruktioner efter danske forhold.

Der er givet udførlige forklaringer med referencer til lærebøger.

\*24 examples have been worked out. They should illustrate the statical calculations and design of some typical timber structures in accordance with Danish conditions.

Full explanations with references to text books have been given.

RIBERHOLT, H.: Trækonstruktioner, Udformning. (\*Timber Structures, Lay Out. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 129, 1991. 145 s. Kr. 40,- excl. moms.

Notatet giver en indføring i udformningen af nogle typiske trækonstruktioner, så de bliver hensigtsmæssige mht. træets og forbindelsesmidlernes egenskaber og styrker. Notatet er koncentreret omkring de specielle forhold for trækonstruktioner.

Både hovedkonstruktionerne og de sekundære konstruktioner er behandlet. Det er tilstræbt at vise, hvordan disse bør udformes, for at de kan indgå i en moderne industrialiseret byggeproces.

\*This publication gives an introduction to the design (not strength verification) or lay-out of some typical timber structures, so that they become appropriate with regard to the properties and strength capacities of the wood and the connections. The publication concentrates on special phenomena in timber structures.

Both the primary structures and the secondary structures are dealt with. It is shown how these should be designed in order to be a part of a modern industrialized construction process.

RIBERHOLT, H.: NBS/T-Seminar – Limning af Trækonstruktioner. (\*NBS/T Seminar. Bonding of timber structures. In Danish). Afdelingen for Bærende Konstruktioner. Serie I, nr. 103, 1991. 90 s.

Seminalet omhandlede limede forbindelser i bærende trækonstruktioner, deres brudmekanismer, styrker, holdbarhed og produktion. Indflydelsen af limtype, metal-træforbindelser og ældning af træoverfladen inden limning blev rapporteret.

Dette skrift indeholder foredragsholderens skriftlige materiale.

\*The seminar dealt with bonded (glued) connections in timber structures, their failure mechanisms, strength, durability and production. The influences of adhesive type, metal-wood connections and aging of the wood surface before bonding were reported.

This publication contains the written material of the lectures.

RIBERHOLT, H.: \*Glulam (Limtræ). International Timber Engineering Conference, London, September, 1991. Proceedings vol. 1, pp. 1.133–1.140.

\*An introduction to the background and status for the European standardization work on glued laminated timber is presented.

Der er givet en indføring i baggrund og status for det europæiske standardiseringsarbejde inden for limtræ.

RIBERHOLT, H.: \*Wooden blades for wind turbines. (Trævinger til vindmøller). International Timber Engineering Conference, London, September, 1991. Proceedings vol. 2, pp. 2.61–2.68. (Reprints available).

\*An account is given of the recent Danish development of wooden blades for large wind turbines. Further, the background for the strength verification of the fatigue strength of the blades and their connections is given.

Der er beskrevet den i Danmark nyligt foregåede udvikling af trævinger til store vindmøller, samt angivet grundlaget for metoder til eftervisning af vingernes og deres befæstigelses udmattelsesstyrke.

RIBERHOLT, H.: \*Neue skandinavische Holzkonstruktionen und Holzkonstruktionsprinzipien. Die neuesten Entwicklungen in der CEN-Standardisierung für Holz und Holzkonstruktionen. (Nye skandinaviske trækonstruktioner og konstruktionsprincipper. Den nyeste udvikling inden for CEN-standarder for træ og trækonstruktioner). Indlæg ved Solothurnisch-Aargauischer Holztag 1991, Tendenzen in modernen Holzbau in Europa, pp. 21, 1991. (Reprints available).

\*An introduction is given to the newest types of Scandinavian timber structures, among these bonded structures and bonded joints. Further, an account is given of the recent development in the elaboration of CEN standards.

Der er givet en indføring i de nyeste skandinaviske former for trækonstruktioner, herunder limede konstruktioner, limede forbindelser. Endvidere er der givet en redegørelse for den nyeste udvikling inden for udarbejdelsen af CEN standarder.

RIBERHOLT, H., BERTIL ENQUIST, PER JOHAN GUSTAFSSON and RALPH BO JENSEN: \*Timber beams notched at the support, December 1991. (Træbjælker med en udskæring ved understøtningen). Afdelingen for Bærende Konstruktioner. Serie R, nr. 280, 1991. 176 s. Gratis.

\*The report deals with wooden beams with a notch cut at the supported end. This results in stress concentrations leading to a severe reduction of the shear force capacity.

A description is given of the test methods used to measure the shear capacities of the notched beams and their mechanical behaviour. Because of the stress singularities the fracture energies of the wood for mode I and II have been determined. The report presents all material properties which have been judged necessary to calculate the shear capacity of a notched beam with a theory based on fracture mechanical concepts such as the fracture energies. The report can thus be employed to verify or calibrate theoretical models.

Further, comparisons are presented between measured and theoretical estimations of the shear capacities of notched beams. It is shown that the analytical model proposed by P.J. Gustafsson overestimates the shear capacity and so does a finite element method based on non-linear fracture mechanics. However, the two models give a reasonable agreement between measured and calculated shear capacities.

Rapporten omhandler træbjælker med en udskæring ved en understøtning. Denne forårsager spændingskoncentrationer, der medfører en væsentlig reduktion af bjælkens forskydningsstyrke.

Der er givet en beskrivelse af forsøgsmetoder anvendt til at måle dels materialeegenskaberne, dels forskydningsstyrken af træbjælkerne ved udskæringerne samt deres mekaniske opførsel. På grund af spændingssingulariteterne er træets brudenergi i mode I og II bestemt. Rapporten præsenterer alle materialeegenskaber, som det er skønnet nødvendigt at måle for at beregne forskydningsstyrken af bjælker med udskæringer med modeller baseret på brudmekaniske begreber som fx. brudenergi. Rapporten kan således benyttes til at eftervise eller kalibrere teoretiske modeller.

Endvidere er der foretaget sammenligninger mellem målte og teoretisk bestemte forskydningsstyrker af bjælker med udskæringer. Det er vist, at den analytiske model foreslået af P.J. Gustafsson overestimerer forskydningsstyrken ligesom en finite element metode baseret på ikke-lineær brudmekanik. De to modeller giver imidlertid en rimelig

overensstemmelse mellem målte og beregnede forskydningsstyrker.

RIBERHOLT, H. og H.J. LARSEN: Trækonstruktioner, Forbindelser. (\*Timber structures, joints. In Danish). SBI-anvisning 140, 2. udg. 1991, 136 s.

Anvisningen behandler forbindelsesmidler til trækonstruktioner og forbindelsernes beregning og udformning. Anvisningen knytter sig til SBI-anvisning 135: Trækonstruktioner, Beregning, og til DIF's normer for bærende konstruktioner.

\*The guidelines cover joints in timber structures and their design and strength verification. The guideline is related to SBI-anvisning 135: Timber structures, Calculation and to DIF's codes of practice.

RIBERHOLT, H. og NIELS MORSING: Limtræ af dansk træ, HQL-planker. (\*Glued laminated timber of Danish timber, HQL-planks. In Danish). Afdelingen for Bærende Konstruktioner. Serie R, nr. 266, 1991. 31 s. Gratis.

Der er udført forsøg til bestemmelse af styrke og stivhed af et specielt optimet dansk træprodukt, HQL-planker. De målte styrke- og stivhedstal er så høje, at HQL-planker er velegnede til fremstilling af limtræ af den bedste danske kvalitet L40. Den høje densitet giver også baggrund for at lave fingerskarringer med den fornødne høje styrke.

\*For the special Danish glued timber product, High Quality Lumber, tests have been carried out to determine its strength and stiffness.

The measured strength and stiffness values are so high that HQL planks are very suitable for the production of glued laminated timber of the best Danish grade L40. The high density enables the production of strong finger joints.

RIBERHOLT, H., se også AAGAARD, NIELS-JØRGEN og H. RIBERHOLT



STANG, H.: \*Prediction of Crack Width in Conventionally Reinforced FRC. (Forudsigelse af Revnevidde i Fiberarmeret Beton med Konventionel Armering). In: Brittle Matrix Composites 3. Eds. A.M. Brandt and I.H. Marshall. Elsevier Science Publishers Ltd., Barking, 1991, pp. 193–203.

\*The model described in the present paper consists of two parts. The first part is a model describing the stress transfer across a discrete crack in the FRC-material as a function of the crack width. This relationship is known as the stress/crack width relationship.

The second part of the model is a plane shear lag model of a reinforcing bar surrounded by FRC-material. Macroscopical cracking is assumed to take place in the FRC material and these macrocracks are characterized by their stress/crack width relationship. Thus, the model is not linear but is derived as a non-linear superposition of two linear solutions.

It is shown that results from existing empirical crack width models are reestablished with the present model when a stress/crack width relationship corresponding to conventional concrete is introduced in the model. Furthermore, crack width predictions for a selection of different FRC-materials are presented.

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

TRABERG, S. og C. DYRBYE: Statik. (\*Statics. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 123, 1991. 113 s. + appendiks 11 s. Kr. 35,- excl. moms.

Bogen indleder med grundlæggende begreber om kræfter og momenter, og ligevægtsbetingelserne formuleres. Understøtningsprincipper gennemgås, og reaktioner i statisk bestemte konstruktioner beregnes. Snitlastbegrebet indføres, og principper for bestemmelse af snitlaster i bjælker og stangkræfter i gitterkonstruktioner gennemgås. I et appendix omtales deformationer i bjælker. Stoffet er belyst med eksempler.

\*The book begins with basic concepts about forces and moments, and the conditions of equilibrium are formulated. Principles of supporting are discussed, and reactions of stati-

cally determinate structures are calculated. The concept of internal actions is introduced, and the principles of determining shear forces and bending moments in beams and normal forces in trusses are given. Deformations of beams are referred to in an appendix. The book includes several numerical examples.

VILMANN, OLE: \*A Harmonic Half-Space Fundamental Solution. (En Fundamental-løsning for et Halvrum). Afdelingen for Bærende Konstruktioner. Serie R, nr. 271, 1991. 130 s. Gratis. /Lic./.

\*The fundamental solution for a harmonic point force in a half-space of a linear elastic medium is established. The fundamental solution consists of the displacements for both a vertical and a horizontal acting point force. The solution is given in cylindrical coordinates.

The solution is based on continuous wavesystems through a second order Fourier transform, i.e. a Hankel transform of the horizontal geometrical coordinates.

The solution of all displacement components from the wave equation is established as infinite horizontal wavenumber integrals, here inverse Hankel transforms. The solution of each displacement component consists of both an analytical part describing the full-space solution and a part describing the influence of the free surface.

Accurate numerical schemes for integration of infinite wavenumber integrals are known to be difficult to establish. Therefore, a complex contour integration technique is used to set up an alternative solution method that for certain source-receiver configurations is more efficient than the direct integration method of the infinite wavenumber integral. It is shown that the two integration methods are efficient in each their complementary parameter domain.

An adaptive numerical integration scheme is set up and tested on an infinite wavenumber integral with known analytical solution. The established adaptive numerical integration scheme is used for computation of one fundamental solution displacement component as an example.

Possibilities of alternative solution methods and alternative numerical integration schemes and aspects by use of the established fundamental solution in a boundary element method code are finally discussed.

En fundamentalløsning i form af alle flytningskomponenter fra både en lodret og en vandret harmonisk kraft virkende i et halvueligt elastisk kontinuum opstilles. Løsningen er opstillet i cylindriske koordinater.

Løsningen baseres på løsningsmetoder ved hjælp af kontinuerte bølgesystemer. Herved opstilles de styrende ligninger til løsning af flytningskomponenterne i det Hankeltransformerede rum baseret på bølgetal.

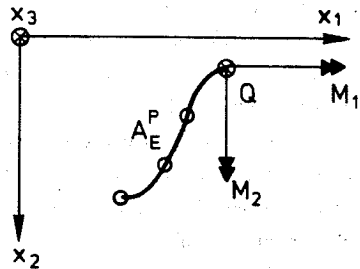
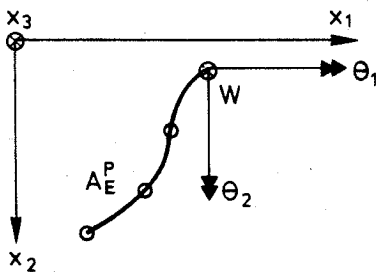
Løsningen af flytningskomponenterne fra bølgeligningen fremkommer som en invers Hankeltransformation, dvs. et uendeligt bølgetalsintegral. Løsningen for hver flytningskomponent består af en analytisk løsning, der beskriver løsningen i et uendeligt rum, og en løsning, der beskriver indflydelsen af den frie overflade.

Numerisk løsning af uendelige bølgetalsintegraler er svære at løse med tilstrækkelig nøjagtighed for visse placeringer af kilde og modtagere, hvorfor kompleks funktionsteori benyttes til opstilling af en alternativ løsning, der for visse placeringer af kilde og modtagere er numerisk mere effektiv end det tilsvarende sædvanlige bølgetalsintegral.

Det vises, at de to løsningsmetoder er numerisk effektive i hver deres komplementære parameterrum.

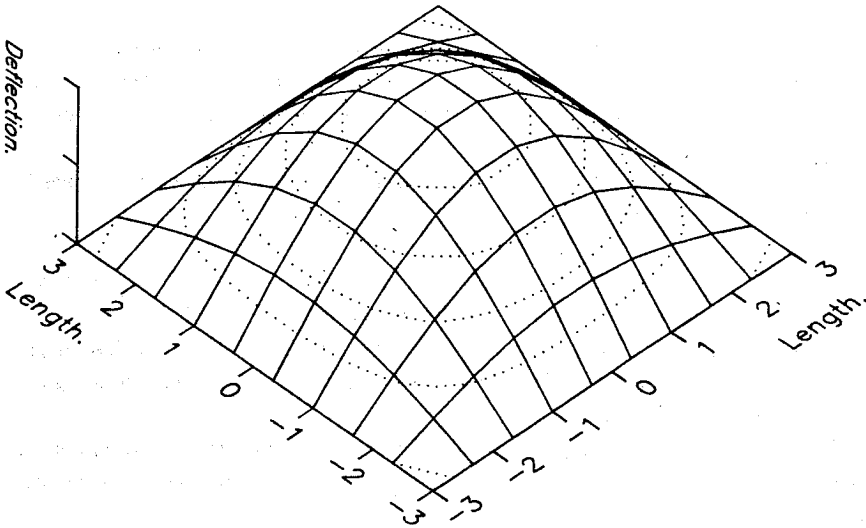
En adaptiv numerisk integrationsmetode opstilles og testes på et simpelt bølgetalsintegral, hvis analytiske løsning er kendt. Den opstillede adaptive numeriske integrationsmetode benyttes dernæst, som eksempel, til beregning af en flytningskomponent.

Slutteligt diskuteres muligheder for alternative løsningsmetoder og mulighederne for randelementmetoden baseret på en fundamentalløsning som den, der beskrives.



Generaliserede randstørrelser for pladen.

\*Generalized plate quantities.



Nedbøjninger af en simpelt understøttet kvadratisk plade belastet med en ensformig fordelt tværbelastning og membrantrykkræfter.

\*Deflections of a simply supported square plate loaded by a uniform transverse load and with a compressive membrane force.

Ref.: Vilmann, Ole: The Boundary Element method applied in Mindlin Plate Bending Analysis. (s. 43).

VILMANN, OLE: \*The Boundary Element method applied in Mindlin Plate Bending Analysis. (Randelementmetoden til Mindlin Plade Beregning). Afdelingen for Bærende Konstruktioner. Serie R, nr. 272, 1991. 151 s. Gratis. /Lic./.

\*The present report describes the boundary element method established through Betti's reciprocal theorem for plate bending analysis.

The problem of evaluating the fundamental solution for the Mindlin plate theory is an essential subject in this report. The fundamental solution for a concentrated transverse force and a concentrated bending moment is formulated and solved.

The boundary element method is formulated based on a four node boundary element and tested on some plate bending problems. Furthermore, the boundary element formulation is expanded to include inplane forces in the plate leading to an iterative boundary element scheme.

Finally, the expanded boundary element formulation is tested on some examples including compressive and tensile inplane forces.

I rapporten gives en fremstilling af randelementmetoden, formuleret på basis af Betti's sætning til analyse af generaliserede flytninger og spændinger i en plade.

Et væsentligt problem i opstillingen af randelementmetoden er fremskaffelse af passende fundamentalløsninger, der knytter sig dels til metodens teoretiske baggrund og dels til problemet, der ønskes en fremstilling af.

Fundamentalløsningen baseret på Mindlin's pladeteori er opstillet og løst. Et randelement er opstillet på basis af den fundne fundamentalløsning og anvendt på nogle statiske, lineære pladeproblemer.

Dernæst er randelementmetodeformuleringen udvidet til at medtage stabiliserende eller destabiliserende skivekræfter. Den fremkomne iterative randelementmetodeformulering er anvendt på nogle eksempler.

YIN, XIAOQING: \*Constitutive Equations and their Application in Finite Element Analysis. (Konstitutive Ligninger for Beton og deres Anvendelse i Elementmetoder). Afdelingen for Bærende Konstruktioner. Serie R, nr. 269, 1991. 114 s. Gratis. /Lic./.

\*This publication consists of the following two parts:

- Part I: Constitutive equations for concrete
- Part II: Constitutive modeling of post-crack behavior of reinforced concrete and its finite element analysis.

Part I summarizes the nonlinear properties of concrete and reviews eight kinds of constitutive relation theories that describe the nonlinear properties. Under each theory, a number of established constitutive models of concrete and their applications are evaluated and discussed.

Part II concerns the constitutive modeling of reinforced concrete in plane stress cases, in which the post-crack behavior of reinforced concrete is mainly considered.

To model the post-crack properties of reinforced concrete, three aspects should be taken into account as follows: (1) The direction of the cracks may change as the strain state changes; (2) Tension stiffening is a property of both reinforcement and concrete. A so-called 'continuity index' as a main factor is introduced to reflect the characteristics of reinforcement and concrete; (3) The compressive strength of concrete is reduced due to the cracks.

Based on the above considerations, a constitutive model of reinforced concrete, so-called 'changing crack model', is established. The crack direction is regarded as a variable in the model.

By using the proposed constitutive model, a plane stress computational program and a 2-dimensional nonlinear finite element program have been developed. Some reinforced concrete specimens – panels subjected to in-plane forces and a T-beam which fails in shear are analyzed and the numerical results of load-deformation responses, crack direction changes, stress-strain curves and stresses in shear reinforcement are compared with the experimental data.

The influences of crack direction change, tension stiffening property and the sensitivity of the shear retention factor are discussed in the numerical examples.

Nærværende rapport er opdelt i 2 dele,

Del I: Konstitutive betingelser for beton

Del II: Konstitutiv modellering af revnet armeret beton, samt analyse af samme ved et elementmetodeprogram.

I del I er betons ikke-lineære egenskaber kort beskrevet, og 8 forskellige teorier omkring de konstitutive betingelser gennemgået. Under hver teori er der diskuteret og evalueret en række af de til dato fremsatte konstitutive modeller for beton.

Del II omhandler den konstitutive modellering af armeret beton udsat for plane spændingstilstande, idet der er fokuseret på den revnede betons opførsel.

Til at modellere revnet betons egenskaber er følgende 3 forhold fastlagt: (1) Revneretningen kan ændre sig i takt med, at tøjningsfeltet ændres; (2) 'Tension stiffening' er en egenskab ved både armering og beton. Et såkaldt kontinuitets-indeks er introduceret som en vigtig faktor for at beskrive armering og beton; (3) Betonens enaksede trykstyrke mindskes efter revnedannelsen.

På baggrund af de ovenstående forhold er en konstitutiv model for armeret beton, en såkaldt 'changing crack model', foreslået. I denne model er revneretningen betragtet som værende variabel.

Med den foreslåede model som baggrund er følgende to EDB-programmer udviklet, dels et program til at analysere en plan spændingstilstand, og dels et 2-dimensionelt ikke-lineært elementmetodeprogram. En række forsøgslegemer af armeret beton er blevet analyseret, dels paneler udsat for skivekræfter, og dels bjælker udsat for forskydning. De numeriske resultater for hhv. last-deformations opførsel, ændring af revneretning, spændings-tøjnings kurver og armeringsspændinger er sammenlignet med forsøgsresultaterne.

Indflydelsen af ændringen af revneretningen, 'Tension stiffening' og følsomhed af 'the shear retention factor' er gennemgået i gennemregnede eksempler.

AAGAARD, NIELS-JØRGEN og H. RIBERHOLT: Optimering af Konstruktioner.

Oktober 1991. (\*Optimization of structures. Oktober 1991. In Danish). Afdelingen for Bærende Konstruktioner. Serie F, nr. 126, 1991. 47 s. Kr. 20,- excl. moms.

Der er givet en oversigt over nogle metoder til og konsekvenser af optimering af konstruktioner.

\*An overview of some methods for and consequences of optimization of structures is presented.

## 2. REKVIREREDE UNDERSØGELSER

### \*Reports on contract work

Rapporten over en rekvireret undersøgelse er principielt rekvirentens ejendom, men dels kan der altid gives rent orienterende oplysninger om, hvad Afdelingen kan udføre af målinger på det pågældende felt ved henvendelse til den person, der er angivet under sagen, og dels er det muligt i visse sager at udlevere en fotokopi af rapporterne, dersom rekvirenten har givet sin tilladelse hertil.

\*A report on contract work is, in principle, the property of the client, but information on the types of measurement undertaken by the Department in the field in question can always be obtained by application to the person named under the project, and for certain projects, a photocopy of the reports can be supplied provided the client has given his consent to this.



I 1991 har Afdelingen gennemført forholdsvis få rekvirerede undersøgelser, herunder bl.a. afprøvning af limtræsmaterialet til en møllevingesektion, som beskrevet nedenfor. Se også Resuméoversigt 1987 og 1990.

Dette forhold er i det væsentlige en følge af, at Afdelingens forsøgskapacitet i perioden i overvejende grad har været knyttet til meget omfattende aktiviteter inden for det materialeteknologiske udviklingsprogram under Teknologistyrelsen, bl.a. vedrørende Cementbaserede Kompositmaterialer og Højstyrkebeton.

\*During 1991 the Department only performed a rather small amount of contract work, among which tests on the gluelam material for a wind turbine blade are described below (see also Summaries of Papers 1987 and 1990).

This reduction in contract work is mainly due to the fact that the experimental capacity of the Department during this period was utilized on extensive investigations under the Danish Materials Technology Development Program, such as Cementbased Composite Materials and High Strength Concrete.

Ekspérimentel bestemmelse af udmattelsestrykstyrke for limtræ. (\*Experimental determination of the fatigue strength in compression of gluelam. In Danish). ABK, serie S nr. 9035.

ABK har for Danske Elværkers Forenings Udredningsafdeling foretaget en initierende undersøgelse af udmattelsestrykstyrken for limtræ til sammenligning med den statiske trykstyrke.

Det anvendte limtræsmateriale er identisk med materialet anvendt til møllevingerne ved forsøgsvindmøllen ved Nibe.

Prøvningen er gennemført i Afdelingens 1 MN Amsler hydrauliske veksellastprøvemaskine ved en forsøgsfrekvens på ca. 9 Hz.

I forsøgene er opnået udmattelsesbrud (ca. 10 – 20 mio. pulsationer) ved trykbelastninger svarende til 50 – 60% af limtræs materialets statiske trykstyrke.

Rekvirent: DEFU.

Yderligere oplysninger: Finn Johnsen og Jørgen Bjørnbak-Hansen, ABK.

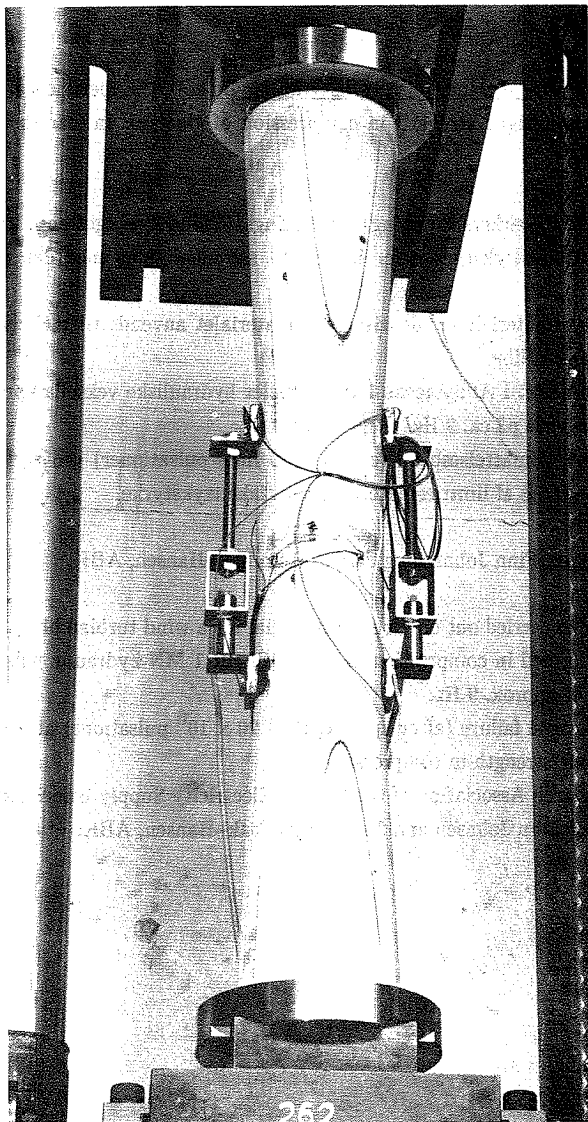
\*Fatigue tests have been carried out on gluelam material for a wind turbine blade.

The tests were performed in compression in an AMSLER 1 MN hydraulic pulsator at a frequency of testing of approx. 9 Hz.

The tests showed fatigue failure (after approx. 10 – 20 x 10<sup>6</sup> pulsations) at a level of 50 – 60 pct. of the static strength in compression.

Client: DEFU (Research Association of the Danish Electricity Supply Undertakings).

Further information: Finn Johnsen and Jørgen Bjørnbak-Hansen, ABK.



Udmattelsesforsøg med limtræ. Trykbelastning fra 30 – 300 kN. Frekvens 9 Hz.

\*Fatigue test on gluelam. Compressive load from 30 – 300 kN. Frequency of testing 9 Hz.

Ref.: Afdelingen for Bærende Konstruktioner, Sagsrapport, Serie S nr. 9035. (s. 49).

### 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.

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\*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.

DAHL, HANS: Stabilitet af Vlasov-bjælker med varierende tværsnitshøjde. (\*Stability of tapered Vlasov-beams. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 48 s. + bilag. Fotokopi, kr. 48,—.

I mange stålrammekonstruktioner indgår bjælkeelementer, hvor tværsnitshøjden varierer. Stabilitetssvigt i form af f.eks. kombineret bøjning og torsion kan være dimensionsgivende, og det er derfor af interesse at udvikle en beregningsmetode, der tager hensyn til tværsnitsvariationen. På basis af en elementmetodeformulering opstilles et bjælkeelement baseret på Vlasov's bjælke-teori. Tværsnitsvariationen indgår ved numerisk integration af stivhedsmatricen og den geometriske matrice. Resultaterne sammenlignes med egentlige 3-dimensionale skalberegninger udført med elementmetodeprogrammet Pafec, og overensstemmelsen er god selv for relativt store tilspidsninger.

Lærer: Lars Damkilde.

\*Tapered beam elements are used in many steel-frame structures. In some cases instability in the form of combined bending/torsion buckling determines the design, and it is therefore of interest to formulate a method of analysis which accounts for the tapering. Based on a finite element formulation a beam element based on Vlasov's beam theory is formulated. The tapering is taken into account by numerical integration of both the stiffness matrix and the geometric matrix. The results are compared with 3-dimensional shell models calculated by the finite element program Pafec. The agreement is excellent even for elements with a large ratio of tapering.

Project leader: Lars Damkilde.

EBBESEN, POUL og PETER DE JONG: Residualspændinger i tyndpladekonstruktioner. (\*Residual stresses in thin-walled structures). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 197 s. + bilag. Fotokopi, kr. 197,—.

Forsøg på Statens Byggeforskningsinstitut har vist, at residualspændinger hidrørende fra koldbukning har betydning for stabilitetslasten af tyndvæggede bjælke/søjle elementer. I rapporten opstilles en model til beskrivelse af koldbukningens indvirken på residualspændingsfordelingen, og der opstilles en forenklet beregningsmetode. Til bestemmelse af stabilitetslasten for tyndvæggede bjælkeelementer med residualspændinger opstilles en ele-

mentmetodeløsning, der både tager hensyn til ikke-lineære geometriske og materialemæssige effekter.

Lærer: Lars Damkilde.

\*Experiments at the Danish Building Research Institute have shown that residual-stresses from the cold-forming process influence the stability load of thin-walled members. In the report a model of the cold-forming process is formulated, and an approximate calculation method for the residual-stress distribution is established. A finite element method for calculation of the buckling load for thin-walled members with residual stresses is formulated. The method accounts for both geometric and material nonlinearities.

Project leader: Lars Damkilde.

#### HANSEN, TORBEN, se NIELSEN, FRANK GJERUM og TORBEN HANSEN

JACOBSEN, KIM og MIKAEL BOE LARSEN: Sammenkobling af CAD- og CAE-systemer – et eksempel på anvendelse af systemplanlægningsværktøjer til data-modeller og dataudveksling. (\*Integration of CAD- and CAE-systems – an example of application of system planning for datamodelling and dataexchange. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner og Institutet for Husbygning, 1991, 83 s. + bilagsrapporter. Fotokopi, kr. 83,-.

Formålet med projektet er at opstille et eksempel på en sammenkobling af design- og analyseprogrammer. Udgangspunktet tages i elementbyggeri, hvor det er ønskeligt automatisk at kunne beregne belastningen på de enkelte elementer ud fra tegninger af konstruktionen. Tegningerne forudsættes lavet med Point, der er et tegne/modelleringsystem baseret på AutoCad specielt rettet mod byggesektoren. Beregningsmodellen opbygges interaktivt i AutoCad vha. en applikation, der er udviklet i projektet. Ved senere ændringer i tegningsmaterialet er applikationen i stand til automatisk at opdatere beregningsmodellen, således at der altid er overensstemmelse mellem tegning og beregningsmodel. I projektet er anvendt systemplanlægningsværktøjer baseret på bl.a. IDEF.

Lærere: Lars Damkilde (ABK) og Egil Borchersen (IFH).

\*The aim of the project is to establish an example of integration between programs for design and analysis. Design of prefabricated houses is chosen as an example. For design purposes it would be useful to calculate the loads on the individual elements from the drawing data. The drawings are produced with Point, which is a drawing/modelling system based on AutoCad with special applications for design of building structures. The analysis model is defined interactively in AutoCad with a special application, which is developed in the project. If the drawings are edited the application can automatically update the analysis model, and thereby secure consistency between the drawings and analysis. In the program development system planning based on e.g. IDEF was used extensively.

Project leaders: Lars Damkilde (ABK) and Egil Borchersen (IFH).

JAGD, LARS KRISTIAN: FEM-modellering af silo-tømmning. (\*FEM-modelling of silo emptying. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1992, 135 s. Fotokopi, kr. 135,-.

Et elementmetodeprogram til beregning af tønningsprocessen i en silo er blevet udviklet. Under tønnning af en silo vil visse dele af silomediet være faste og andre dele strømmende. De faste dele modelleres elasto-plastisk, og de strømmende ikke-lineært viskøst. Densitetsafhængighed er taget i betragtning.

Opførsel der ligner masse- og tragt-strømninger kan opnås. Mange af resultaterne er dog vanskelige at tolke og kræver yderligere undersøgelser. Desuden bør modellen forbedres på en række punkter, ligesom materialeparametrene kræver supplerende eksperimentelt arbejde.

Lærer: Leif Otto Nielsen.

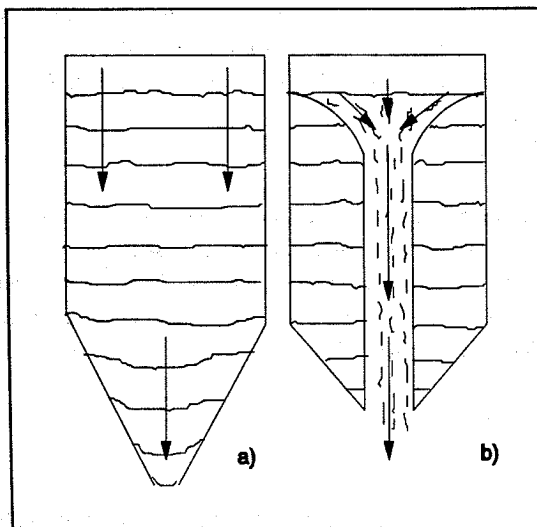
\*A finite element program for computation of the emptying process in a silo has been developed. The emptying process results in solid and flowing parts in the silo-medium.

The solid parts are modelled elasto-plastic and the flowing parts nonlinear viscously. The density dependence is included.

Behavior like mass flow and funnel flow are possible. However, many of the results are difficult to interpret and improvements of the model and the material parameters seem

to be an important future task.

Project leader: Leif Otto Nielsen.



Strømningsformer i silo: a) Massestrømning, b) Tragtstrømning.

\*Flow patterns in silo: a) Mass flow, b) Funnel flow.

Ref.: Jagd, Lars Kristian: FEM-modellering af silotømning. (s. 54).

JONG, PETER DE, se EBBESEN, POUL og PETER DE JONG

LARSEN, MIKAEL BOE, se JACOBSEN, KIM og MIKAEL BOE LARSEN



LARSEN, THOMAS: Bærende konstruktion af aluminium til væksthuse. (\*Aluminium alloy structures for green-houses. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 131 s. Fotokopi, kr. 131,-.

I rapporten belyses fordelene og ulemperne ved at anvende ekstruderede profiler af aluminium til opførelse af store væksthuse.

Der er i samarbejde med en produktionsvirksomhed inden for fremstilling af aluminium-profiler udarbejdet forslag til profiltyper og samlingsbeslag og metoder, som vil virke hensigtsmæssige under såvel montering som daglig anvendelse (bæreevne, deformation, vandafledning m.v.).

Lærer: Claus Philipsen.

\*In the thesis the advantages and disadvantages of the use of extruded profiles of aluminium for the construction of large green-houses are analysed.

In cooperation with a concern for the production of aluminium profiles, proposals have been worked out for types of profiles and fittings and methods of assembling which will work appropriately during both fitting and daily use (carrying capacity, deformation, drainage etc.).

Project leader: Claus Philipsen.

NIELSEN, FRANK GJERUM og TORBEN HANSEN: Projekteringsystem til Beton-konstruktioner. (\*Design System for Concrete Structures. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 105 s. + bilagsrapporter. Fotokopi, kr. 105,-.

Rapporten omhandler udvikling af et interaktivt system til projektering af betonkonstruktioner. Systemet tager hensyn til den praktiske anvendelighed, og der kan f.eks. både foretages indledende overslagsberegninger samt detailberegninger. Programmet er udviklet i Turbo-Pascal med mulighed for at anvende objekt-orienteret programmering. Den objektorienterede fremgangsmåde gør det lettere at opbygge en fleksibel struktur, hvor data knyttes sammen med deres anvendelse, og hvor egenskaber kan arves fra overordnede niveauer.

Lærer: Lars Damkilde.

\*The report describes implementation of an interactive system for design of concrete structures. The system is designed with emphasis on the practical use, and it is for example possible to make an initial estimate as well as a detailed analysis. The program is written in Turbo-Pascal with objectoriented facilities. The object-oriented programming makes it easier to design a flexible system, where data are connected to their application, and where information can be inherited from superior levels.

Project leader: Lars Damkilde.

NIELSEN, PETER GAMBORG og HUYNH TRUONG TRUC: Broer med hænge-, skråstags- og kombisystemer. (\*Suspension bridges, cable-stayed bridges and combined systems. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 223 s. + bilag. Fotokopi, kr. 223,-.

Der er foretaget sammenlignende beregninger af hængebroer, skråstagsbroer og kombinationer af disse systemer. Som eksempel på en hængebro er benyttet den projekterede Østbro over Storebælt, mens de andre brotyper har samme spændvidde som hængebroen. Til beregningerne er benyttet et eksisterende EDB-program, hvor broen behandles som en plan konstruktion, og virkningen af endelige flytninger (geometriske ulineariteter) medregnes. Programmet er modificeret, således at konvergenssegenskaberne forbedres, og pyloner med variabelt tværsnit kan behandles. Nedhængseffekten for skråstagnene medregnes også.

Lærere: Niels J. Gimsing og Hugo Møllmann.

\*Suspension bridges, cable-stayed bridges, and combinations of these systems have been analysed and compared. The existing design for the East Bridge across the Great Belt in Denmark has been used as an example of a suspension bridge, while the other types of bridges have the same span as the suspension bridge. An existing computer program was used for the analyses, in which the bridge is treated as a plane structure, and the effects of finite displacements (geometric nonlinearities) are accounted for. The program has been modified, so that the convergence properties are improved, and pylons of variable cross-section can be included. The effect of cable sag in the stays is also taken into account.

Project leaders: Niels J. Gimsing and Hugo Møllmann.

PEDERSEN, CARSTEN: Optimering af fiberbetonkonstruktioner. (\*Optimization of FRC-structures. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 66 s. + appendiks. Fotokopi, kr. 66,-.

Projektet præsenterer en analytisk model til beregning af revnevidder og -afstande i fiberarmerede jernbetonkonstruktioner. Den gør det muligt at vælge den gunstigste fiber-type samt at kombinere de optimale mængder af fiberarmering og konventionel armering.

Der gives eksempler på beregning af bjælker, plader og vægge. Elementernes økonomi vurderes.

Undersøgelserne giver et stærkt fingerpeg om, at der i konstruktioner med store krav til revnevidder kan opnås betydelige besparelser ved at erstatte dele af den konventionelle armering med fiberarmering.

Lærere: H. Stang og H. Krenchel.

\*The project presents an analytical model to calculate crack widths in conventionally reinforced structures using fiber-reinforced concrete. The model makes it possible to choose the most appropriate fiber type and to combine the optimal amounts of fiber and conventional reinforcement.

An example is given on the calculation of beams, plates and walls together with a detailed price evaluation.

The analysis presented clearly indicates that significant savings can be attained in constructions which impose stringent requirements to crack widths. This is obtained by substituting conventional reinforcement parts with fiber reinforcement.

Project leaders: H. Stang and H. Krenchel.

RASMUSSEN, TORBEN VALDBJØRN: Fibercements mekaniske egenskaber. (\*Mechanical properties of fibre reinforced cement. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 223 s. incl. app. + 102 s. Bruger- & Programdokumentation + 243 s bilag (forsøgsresultater). Fotokopi, kr. 578,-.

Tre arbejdsområder er behandlet; trækprøvningsforsøg, teoretiske betragtninger samt udvikling af et EDB-program.

Det betragtede kompositmateriale består af cementmørtel armeret med i princippet uendeligt lange KRENIT fibre orienteret i spændingsaksens retning. Disse påvirkes til enakset træk efter hovedretningen.

Teorien beskriver revneudviklingen for det betragtede kompositmateriale.

EDB-programmet beregner kompositmaterialets trækarbejdskurve for op- og aflastning.

Der er opnået smuk overensstemmelse mellem teoretisk og målt arbejdskurveforløb.

Lærere: Henrik Stang og Herbert Krenchel.

\*The purpose of the project was to investigate the uniaxial tensile characteristics of fiber reinforced mortar under static and cyclic loading. The subject is treated both experimentally and theoretically.

The tested composite material was made of mortar reinforced with continuous aligned KRENIT fibres orientated along the load direction.

The theory describes the crack development in the composite material.

An EDP-program is developed which describes the stress-strain curves for the composite material both under static and cyclic loading.

Close correlation has been observed between the experimentally established stress-strain curves and the model.

Project leaders: Henrik Stang and Herbert Krenchel.

SIGURDSSON, TORFI G: Gennemlokning i beton ved excentrisk belastning. (\*Punching in Concrete at Eccentric Loading. In Danish). Eksamensprojekt, Afdelingen for Bærende Konstruktioner, 1991, 111 s. + 120 s. app. Fotokopi, kr. 231,-.

Ved bestemmelse af gennemlokningsbæreevnen for armerede betonplader er der i projektets første fase undersøgt centralt belastede indre plade-søjle forbindelser.

En teoretisk beregningsmodel baseret på plasticitetsteorien er sammenlignet med ca. 140 forsøg fra litteraturen. På baggrund af denne sammenligning er der modificeret på den såkaldte effektivitetsfaktor  $\nu$ , idet der blev konstateret en afhængighed ikke alene af betonens trykstyrke  $f_c$  men også af pladetykkelsen  $h$  og armeringsprocenten  $\varphi$ . Modellens beregnede gennemlokningsbæreevne sammenlignet med de eksperimentelt

fundne viser en udmærket overensstemmelse. Variationskoefficienten blev bestemt til 15,9%.

I projektets anden fase blev en teoretisk model baseret på plasticitetsteorien til bestemmelse af gennemlokningsbæreevnen for excentrisk belastede plade-søjle forbindelser opstillet. Modellens resultater er sammenlignet med de i litteraturen fundne empiriske formler og med de sparsomme forsøg, som kunne fremskaffes. Det må konstateres, at de empiriske formler alle giver en stor spredning. Ved en sammenligning mellem det teoretisk opstillede udtryk og forsøgsresultaterne findes en udmærket overensstemmelse. Variationskoefficienten var 16,0%.

Lærere: M.P. Nielsen og David Holkmann Olsen.

\*Punching shear in reinforced concrete slabs is investigated in the first part for central loading. A theoretical solution based on the theory of plasticity is compared with appr. 140 tests found in the literature. The existing effectiveness factor  $\nu$  is modified and made dependent not only on the compressive strength of concrete but also on the thickness of the slab and the reinforcement degree. The theoretical punching load carrying capacity is compared with test results and a good agreement is found. The variation coefficient was 15,9%.

In the second part a theoretical model based on the theory of plasticity is derived for the punching strength of eccentrically loaded concrete slabs. A comparison between the model, empirical formulas and a few test results assembled from the literature is made. The empirical formulas suggested in the literature all reveal a great scatter when compared to test results. The model, however, reveals a good agreement when compared to test results. The variation coefficient was 16,0%.

Project leaders: M.P. Nielsen and David Holkmann Olsen.

TRUC, HUYNH TRUONG, se NIELSEN, PETER GAMBORG og HUYNH TRUONG TRUC

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