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CONTENTS

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DISCUSSION

Proc. Paper 11271

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[a]Discussion period closed for this paper. Any other discussion received during this discussion period will be published in subsequent Journals.

TECHNICAL NOTES

Proc. Paper 11277

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[a]Discussion period closed for this paper. Any other discussion received during this discussion period will be published in subsequent Journals.

11295 INELASTIC I-BEAMS UNDER MOMENT GRADIENT

KEY WORDS: **Beams (supports); Buckling;** Flexural strength; **I beams;** Inelastic action; Moments; **Stability; Structural engineering;** Torsion

ABSTRACT: A model developed for the inelastic buckling of beams under uniform moment, which accounts for strain-hardening residual stresses and monosymmetry of the yielded cross section, is extended to the case of moment gradient by allowing for the effects of nonuniform yielding. A tangent modulus theory of buckling is used, and the governing differential equations are adopted from those which govern the elastic flexural-torsional buckling of tapered monosymmetric I-beams of constant depth. The critical central concentrated loads of simply supported I-beams are obtained by solving the governing differential equations numerically by using the method of finite integrals in an iterative process. The influence of the residual stresses, height of point of application of the load, and in-plane moment distribution on inelastic buckling are investigated, and the theoretical solutions are compared with design rules.

REFERENCE: Kitipornchai, Sritawat, and Trahair, Nicholas S., "Buckling of Inelastic I-Beams under Moment Gradient," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11295**, May, 1975, pp. 991-1004

11297 MULTISTAGE OPTIMIZATION OF STRUCTURES

KEY WORDS: Computer programming; Constraints; Decomposition; **Dynamic programming;** Frames; **Minimum weight design; Optimization;** Redundant components; **Structural engineering;** Trusses; **Variables**

ABSTRACT: The design optimization problem is formulated as a multistage decision system by decomposing the structure into a series of substructures. The adoption of indeterminate forces as the state variables in a dynamic programming formulation is shown to be an effective means to describe truss and frame structural systems. A set of decomposition principles are presented which relate static indeterminacy, the number and position of the external reactions, and the stability of the structures corresponding to each stage. Design constraints on the individual members are considered by the concept of constrained policy space for the force state variables. A discrete programming technique is developed for elastic frame optimization problems in which member sizes are restricted to standard structural shapes.

REFERENCE: Twisdale, Lawrence A., and Khachaturian, Narbey, "Multistage Optimization of Structures," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11297**, May, 1975, pp. 1005-1020

11302 MULTISTORY MULTIBAY FRAMES

KEY WORDS: Approximation method; **Bays (structural); Buildings; Deflection; Frames;** Lateral forces; **Stresses; Structural engineering; Tall buildings**

ABSTRACT: An approximate analysis of multistory, multibay elastic frames subjected to static lateral loads is developed. The approximation is made that the axial deformations of the columns have hyberbolic sine variation across the width of the building. Assuming points of contraflexure at the mid-heights of the columns and at the midspans of the connecting beams and using the energy approach permits the development of a set of two coupled differential equations. These can be reduced to one equation the solution of which can be written explicitly for each loading condition. Examples comparing results with those obtained by the "exact" stiffness matrix method show that the method yields acceptably accurate deflections, axial stresses, and column shears. Design curves for the rapid determination of these parameters are included.

REFERENCE: Chan, Paul C.K., Heidebrecht, Arthur C., and Tso, Wai K., "Approximate Analysis of Multistory Multibay Frames," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11302**, May, 1975, pp. 1021-1035

KEY WORDS: **Control theory;** Elastic theory; **Force; Interactions;** Joints (connections); Loads (forces); **Optimization; Optimum design;** Structural design; **Structural engineering; Substructures; Trusses;** Variables

ABSTRACT: A method is given for the optimum design of linearly elastic trusses which can be partitioned into a series of statically determinate substructures. In the case of such structures the design problem is formulated as a problem in optimal control theory. The member areas of substructures are treated as control variables and the interacting forces between substructures are taken as the state variables. Transformation equations for state variables are derived using equilibrium and displacement compatibility conditions. The design problem is envisaged as a problem of determining optimal controls to minimize the weight of the truss. This necessitates the solution of a number of smaller problems in sequence, instead of a single problem of larger dimension. Solution of the resulting optimal control problem can be obtained using the method of local variations.

REFERENCE: Singaraj, Narasingam M., and Sridhar Rao, Jawalker K., "Optimization in Trusses Using Optimal Control Theory," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11304**, May, 1975, pp. 1037-1051

11311 STRENGTH DECAY OF RC COLUMNS UNDER SHEAR

KEY WORDS: **Columns (supports); Concrete (reinforced);** Earthquakes; Research; **Shear strength;** Strength; **Structural engineering; Testing**

ABSTRACT: The decay in shear strength of tied reinforced concrete columns during earthquake loading was investigated by subjecting 12 column specimens to several reversals of loading to deflections larger than the yield deflection. The principal variables of the test program were the axial load, the transverse reinforcement ratio, and the total deflection per cycle. The test specimens were able to develop the expected yield moment in the first quarter cycle and maintain that load for some inelastic deflection. However, the repetition of these deflections resulted in a decay in the strength of the member. Experimental data are used to examine the mechanism of strength decay, which is related to crushing and spalling of the shell concrete, yielding of the transverse reinforcement, and abrasive rubbing of concrete along inclined cracks. The results of this investigation indicate that the transverse reinforcement must be proportioned to carry the total shear required to develop the ultimate moment capacity of the column.

REFERENCE: Wight, James K., and Sozen, Mete A., "Strength Decay of RC Columns under Shear Reversals," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11311**, May, 1975, pp. 1053-1065

11309 SEISMIC DESIGN DECISION ANALYSIS

KEY WORDS: **Benefit-cost ratios; Buildings (apartment); Buildings (codes);** Costs; Damage; Decision making; **Earthquake resistant structures; Earthquakes;** Economics; **Seismic design; Structural engineering;** Systems engineering

ABSTRACT: Seismic design decision analysis is a procedure for organizing into a useful format the information required to arrive at a balance between the cost of designing to give earthquake resistance and the risk of damage and loss of lives in future earthquakes. The likelihood of ground shaking of various intensities is evaluated using Cornell's seismic risk model. Building performance is expressed by damage probability matrices; empirical evidence from past earthquakes — especially the San Fernando, Calif., earthquake — plus theoretical analysis and subjective judgment are used to develop such matrices. The cost of increased seismic resistance is determined by designing a series of typical buildings. All this information is then combined to provide estimates of costs and losses. The apparent conclusion is that design against earthquakes is justified only if one either makes a very consecutive interpretation of the seismic risk or places a very high value on saving lives.

REFERENCE: Whitman, Robert V., Biggs, John M., Cornell, C. Allin, Brennan, John E., III, de Neufville, Richard L., and Vanmarke, Erik H., "Seismic Design Decision Analysis," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11309**, May, 1975, pp. 1067-1084

11323 ULTIMATE STRENGTH OF I-BEAM BRIDGE SYSTEMS

KEY WORDS: **Bridges (structures);** Buildings; **I beams; Reports; Specifications; Structural engineering; Ultimate strength**

ABSTRACT: The load factor design criteria in the 1973 AASHO Specifications represent a step forward, but only a first step in what can be a progression of more advanced design concepts involving: (1) The definition of the resistance and load factors by implicit use of first-order probability theory; (2) the explicit use of probability theory; and (3) optimization of benefits and risks on all levels of performance. The implementation of the first of these steps is now possible with available data on resistance and on loads. Work toward this goal is being performed on steel buildings and tentative criteria for these are now available. The implementation on a sufficient scale of the more advanced steps is still in the future, demanding more refined statistical data and the reduction of complicated analytical methods into practical tools.

REFERENCE: Heins, Conrad P., Chmn., "State-of-the-Art Report on Ultimate Strength of I-Beam Bridge Systems," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11323**, May, 1975, pp. 1085-1096

11298 LOCAL BUCKLING OF LONG-SPAN FOLDED PLATES

KEY WORDS: **Buckling;** Concrete (reinforced); **Folded plates;** Models; Roofs; **Shells (structural forms); Structural engineering**

ABSTRACT: An approximate analysis of a long end-supported folded plate structure with or without transverse stiffeners to predict the load at which a local buckle will appear in one or more of its constituent elements is presented. Based on the observations of numerous experiments of folded plate models subjected to load levels of sufficient intensity to create buckling in a plate element, the local buckle is assumed to be a rectangular or skewed panel which is a portion of a multi-waved buckled surface. This panel, which is subjected to in-plane normal and shearing forces, is analyzed using the energy approach. This approach makes use of stress functions which may be obtained from any of the available general methods of folded plate stress analysis and yields a closed-form solution for the load associated with the local buckle. Comparisons with previous analyses and experimental results are also presented.

REFERENCE: Swartz, Stuart E., Rosebraugh, Vernon H., and Fanjiang, Guang-Nan, "Local Buckling of Long-Span Folded Plates," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11298**, May, 1975, pp. 1097-1109

11322 LOAD TESTS OF BUILDING STRUCTURES

KEY WORDS: Buildings; **Buildings (codes); Loading tests;** Loads (forces); Measuring instruments; **Quality control;** Safety; **Structural engineering;** Testing

ABSTRACT: European practice in load testing buildings is a valuable guide for American structural engineers. Although load tests often are used as legal measures, they can provide valuable insight into structural behavior if this aspect is properly considered. Procedures outlined are for a test project and include a preliminary structural analysis and detailed planning. Consideration of variations in properties of materials is important, as is the static or dynamic characteristics of the service loads. Magnitude, distribution, and duration of test loads are essential factors examined. The actual execution of the test involves three major aspects: (1) Recording of accurate and significant data; (2)safety of personnel and protection of structure; and (3)economy. Even a perfectly executed test needs proper analysis and application of results before it can be considered successful. Some criteria for evaluating test results are given.

REFERENCE: Bares, Richard, and FitzSimons, Neal, "Load Tests of Building Structures," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11322**, May, 1975, pp. 1111-1123

11325 STRENGTH OF REINFORCED CONCRETE BLOCKS

KEY WORDS: **Bearing capacity;** Concrete; **Concrete (blocks); Concrete (reinforced);** Cracking; **Loads (forces); Reinforcement; Stresses; Structural engineering; Tests;** Ultimate loads; Ultimate strength

ABSTRACT: The problem of large forces acting over limited contact areas of concrete arises frequently in engineering design. Although several papers have appeared on the subject, information regarding the effect of reinforcement on the local bearing strength of concrete is rather insufficient. The present paper aims at removing this lack of information by reporting a fairly extensive series of bearing tests on reinforced concrete blocks, where the form and amount of reinforcement were the principal variables.

REFERENCE: Niyogi, Sanat K., "Bearing Strength of Reinforced Concrete Blocks," *Journal of the Structural Division,* ASCE, Vol. 101, No. ST5, **Proc. Paper 11325,** May, 1975, pp. 1125-1137

U.S. CUSTOMARY-SI CONVERSION FACTORS

In accordance with the October, 1970 action of the ASCE Board of Direction, which stated that all publications of the Society should list all measurements in both U.S. Customary and SI (International System) units, the following list contains conversion factors to enable readers to compute the SI unit values of measurements. A complete guide to the SI system and its use has been published by the American Society for Testing and Materials. Copies of this publication (ASTM E-380) can be purchased from ASCE at a price of 75¢ each; orders must be prepaid.

All authors of *Journal* papers are being asked to prepare their papers in this dual-unit format. Until this practice affects the majority of papers published, we will continue to print this table of conversion factors:

To convert	To	Multiply by
inches (in.)	millimeters (mm)	25.40
inches (in.)	centimeters (cm)	2.540
inches (in.)	meters (m)	0.0254
feet (ft)	meters (m)	0.305
miles (miles)	kilometers (km)	1.61
yards (yd)	meters (m)	0.91
square inches (sq in.)	square centimeters (cm^2)	6.45
square feet (sq ft)	square meters (m^2)	0.093
square yards (sq yd)	square meters (m^2)	0.836
acres (acre)	square meters (m^2)	4047
square miles (sq miles)	square kilometers (km^2)	2.59
cubic inches (cu in.)	cubic centimeters (cm^3)	16.4
cubic feet (cu ft)	cubic meters (m^3)	0.028
cubic yards (cu yd)	cubic meters (m^3)	0.765
pounds (lb)	kilograms (kg)	0.453
tons (ton)	kilograms (kg)	907.2
one pound force (lbf)	newtons (N)	4.45
one kilogram force (kgf)	newtons (N)	9.81
pounds per square foot (psf)	newtons per square meter (N/m^2)	47.9
pounds per square inch (psi)	kilonewtons per square meter (kN/m^2)	6.9
gallons (gal)	cubic meters (m^3)	0.0038
acre-feet (acre-ft)	cubic meters (m^3)	1233
gallons per minute (gal/min)	cubic meters per minute (m^3/min)	0.0038
newtons per square meter (N/m^2)	pascals (Pa)	1.00