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CURRENT RESEARCH ON COLD-FORMED STEEL STRUCTURES

by

Asadul H. Chowdhury[1]

I INTRODUCTION

A survey of current research on cold-formed steel structures was conducted at the Department of Civil Engineering, North Dakota State University, Fargo, by the Subcommittee on Current Research and Future Needs of the Committee on Cold-Formed Members, Structural Division, American Society of Civil Engineers. This survey was initiated in March, 1985 and is an update of the earlier survey which was published as Preprint 3763 at the ASCE Annual Convention and Exposition held in Atlanta, Georgia, October 22-26, 1979. The principal purpose of this survey is to assist the Subcommittee in preparing a report on the current research work being conducted in this area, in planning further research, and in making contact with investigators working in their particular area of interest. Another purpose is to provide individuals working on the same topic an opportunity to make contact with one another, and to facilitate similar contacts from industry and government.

More than 120 questionnaires were sent to universities, research institutions, and in industry in the U.S.A., Canada, European countries, Australia, India, China, Japan and South America. Another 30 questionnaires were distributed at the 1985 Structural Engineering Congress in Chicago. Completed questionnaires for 42 research projects in the U.S.A., Canada, U.K., the Netherlands, Australia, and India have been received. This paper reports the responses of all the 42 research projects received through the survey with a brief description on each project.

As in the previous survey, this survey by no means is a complete summary of research in progress in this area, since this paper is only based on the completed questionnaires. The Subcommittee recognizes that there are other current research projects not reported herein.

The research projects have been classified into nineteen major areas, sections II to XX, which are consistent with those used for the Subcommittee on Literature Survey. The individual research projects are listed under the appropriate area. The arrangement of the material within a particular area is alphabetical according to the title of the

1. Assistant Professor of Civil Engineering, North Dakota State University, Fargo, North Dakota, 58105, and Chairman, Subcommittee on Current Research and Future Needs, ASCE Committee on Cold-Formed Members.

project. A number is assigned to each research project.

The first paragraph of each research project includes its number, title and the reference numbers, in parenthesis, of the most significant or current reference if available. The second paragraph gives the names of the principal investigators, the organization where the investigation is being conducted and the name of the sponsor. The third and the subsequent paragraphs provide the abstract or the description of the project which is essentially the same as that furnished by the principal investigators.

II MECHANICAL BEHAVIOR AND COLD-FORMING EFFECTS

2.1 RESIDUAL STRESSES IN THICK (ONE INCH OR MORE) HIGH STRENGTH STEEL PLATES COLD BENT TO VERY TIGHT RADII OF CURVATURE (21).

Richard N. White, Department of Structural Engineering, Cornell University, Ithaca, New York, U.S.A.; Electric Boat Division of General Dynamics.

Steel plates of thickness 1 inch (25.4 mm) and 1.5 inches (38.1 mm) were cold-bent to radii of 1.5, 2.5, 3.5 and 5.5 inches (38.1, 63,5, 88.9 and 139.7 mm), with bend angles of 30, 60, and 90 degrees. HY-80 and HY-100 steel was used. Residual stresses from the cold-bending were measured by sectioning and hole-drilling. Tensile residual stresses on the inner surface of the bent plate ranged from 46% to 92% of the yield stress of the material. Surface strains in excess of 40% were measured on the most severely bent plates, but no surface cracking was observed. Test results were compared with several existing equations; the analytical results are not fully satisfactory. Reasons for the discrepancies are identified in reference 21.

The next step of the research is to study the fatigue life of the bent plates, and to also work with HY-130 steel. The fatigue study will include extensive use of fracture mechanics embedded in interactive computer graphics software.

III STRENGTH OF THIN ELEMENTS

3.1 AUTOMOTIVE STRUCTURAL COMPONENTS USING HIGH STRENGTH SHEET STEELS

Wei-Wen Yu, Department of Civil Engineering, University of Missouri-Rolla, Rolla, Missouri, U.S.A.; American Iron and Steel Institute.

The objectives of this project include (a) determination of the characteristics of high strength automotive sheet steels which influence their performance in structural applications, (b) structural strength of automotive structural components, and (c) improvement of the current design criteria and development of the new design criteria.

3.2 MECHANICAL BEHAVIOR OF COLD-FORMED SECTIONS AND DRAFTING OF DESIGN RULES (18).

A.W. Toma, IBBC-TNO, P.O. Box 49, 2600 AA Delft, The Netherlands, and John Rhodes, Department of Mechanics, University of Strathclyde, Glasgow, Scotland, U.K.; European Economic Community-Dutch and British Industries.

The aim of the program is to draft "users-friendly" design rules. The different subjects being studied are (a) Post-critical behavior of unstiffened elements, edge stiffened elements and intermediately stiffened elements, and (b) Behavior of beam-systems - stability of linear elements loaded in bending and force introduction in the webs of sections.

3.3 POST LOCAL BUCKLING BEHAVIOR OF NON-UNIFORMLY COMPRESSED UNSTIFFENED ELEMENTS (10).

V. Kalyanaraman and P. Jayabalan, Department of Civil Engineering, Indian Institute of Technology, Madras, 600036, India; Indian Institute of Technology, Madras.

Non-uniformly compressed thin-walled unstiffened elements are encountered in beam-columns. Such elements may undergo local buckling well before yielding and may have considerable post-buckling strength. Effective width equations are available for uniformly compressed stiffened and unstiffened elements for the post-buckling range. However, neither effective width equation nor experimental results are available for the post-buckling behavior of non-uniformly compressed unstiffened elements.

Both analytical and experimental investigation is being carried out to study the post-buckling behavior of non-uniformly compressed unstiffened elements and to arrive at a procedure for the design of non-uniformly compressed thin walled unstiffened elements and members composed of such elements.

IV FLEXURAL MEMBERS

4.1 ADEQUACY OF PROPOSED AISI EFFECTIVE WIDTH SPECIFICATION PROVISIONS FOR Z- AND C-PURLIN DESIGN

Thomas M. Murray, Department of Civil Engineering, University of Oklahoma, Norman, Oklahoma, U.S.A.; Metal Building Manufacturers Association.

Using experimental data from a number of independent sources, the adequacy of proposed changes in the AISI specification for determining the flexural strength of gravity loaded, C- and Z-purlins is being investigated.

4.2 ANALYSIS AND TESTING OF A LATTICED PORTAL FRAME IN COLD FORMED STEEL

E.R. Bryan, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

This project consists of analyzing a 70.82 ft (21.6 m) span latticed portal frame assuming (1) all joints are pinned, (2) the internal members only are pinned, and (3) all joints are rigid. With this information, the design of the frame is carried out according to the draft BS 5950 Part 5, and compared with the French and American specifications.

A laboratory investigation is carried out on the most critical member. Full scale tests will be made on the frames using (1) bolted and (2) welded connections, and the results will be compared with theory and the design assumptions.

4.3 BEHAVIOR OF NESTED Z-SHAPED PURLINS

Gregory W. Robertson and Carl E. Kurt, University of Kansas, Lawrence, Kansas, U.S.A.; Metal Building Manufacturers Association.

In the design of continuous Z-shaped purlins, the common practice in metal building systems is to nest or overlap adjacent purlins. The objective of this project is to develop a mathematical model and design procedure to describe the shear transfer mechanism within the nested area. Overlap lengths were varied in a series of experimental tests conducted on two different purlin depths. Ultimate moment capability and stiffness were measured. Specimens with very short overlap lengths of 9 inches (228.6 mm) had higher ultimate moment capability than a single purlin. However, overlap lengths approaching 35 inches (889 mm) were required before single purlin stiffness properties were achieved. Based on the results of the experimental data collected, mathematical expressions will be developed to describe the shear transfer mechanism with the nested area.

4.4 DIAPHRAGM BRACED CONTINUOUS Z-BEAMS

L.D. Luttrell, West Virginia University, Morgantown, West Virginia, U.S.A.; Civil Engineering Department of West Virginia University.

A detailed analysis of several data sets is presented along with current full-scale test studies. The often misused $M_c = (GKEI_y)^{0.5}$ bifurcation equation is ignored in establishing an equilibrium approach for flange stresses. A bending equation is then presented in the form of $M = \phi F_b S_x$ where ϕ describes the effects of shape and diaphragm influence usually below 0.8.

4.5 NUMERICAL ANALYSIS OF THIN-WALLED STRUCTURES (3)

Ken P. Chong, Department of Civil Engineering, University of Wyoming, Laramie, Wyoming, U.S.A.; State of Wyoming.

The finite strip and finite layer methods are powerful tools for the analysis of thin-walled structures. In this investigation, the finite strip method is applied to study the behavior of cold-formed steel beams including webs with longitudinal stiffeners. Comparisons are made with AISI specifications and published data. The finite layer method is used to investigate the buckling behavior of sandwich panels with thin facings and rigid foam cores. Effects of variable core stiffnesses (due to uneven curing, etc.) on the buckling strength are quantified and presented. Other applications of these numerical methods are being studied.

4.6 STRENGTH OF SIGMA PURLINS

V. Kalyanaraman, Department of Civil Engineering, Indian Institute of Technology, Madras, 600036, India; Press Metal Corporation.

Full scale tests are being carried out using sigma purlin sections in order to improve the performance of the sections. Longer span purlins are made to act continuously over the supports using sigma section sleeves and in shorter spans purlins are made to span two spans in a row.

Both dead and live load and wind load tests are being carried out. Dead and live load tests are carried out on various roof slopes and wind load tests are carried out by testing the purlin upside down.

Through this development considerable improvement in strength over the usually tabulated values has been achieved.

4.7 THE EFFECT OF END SUPPORTS ON THE BEHAVIOR OF BRACED GIRTS AND PURLINS (13)

Dimos Polyzois, Department of Civil Engineering, The University of Texas at Austin, Austin, Texas, U.S.A.; The University Research Institute of the University of Texas at Austin.

Although cold-formed steel members provide substantial savings due to their high strength-to-weight ratio, their cross-sectional configuration gives rise to behavioral phenomena which are not encountered in the more familiar symmetrical sections. Of great concern is the tendency of cold-formed sections to bend and twist under most conditions of loading. The amount of lateral and rotational displacement depends not only on the cross-sectional characteristics of these members but also on the degree of bracing provided both along the span and at the supports.

The present research project deals with a theoretical and experimental investigation on the effect of end supports, such as those provided by clip angles, on the behavior of braced girts and purlins. The experimental investigation involves the testing to failure under suction of three full sized wall units (20 ft x 14 ft (6.1 m x 4.27 m)) consisting of Z-section girts and light gage steel panels.

4.8 THE EFFECT OF WEB DISTORTION ON THE BEHAVIOR OF CHANNEL AND Z-SECTION GIRTS AND PURLINS (6)

Dimos Polyzois, Department of Civil Engineering, The University of Texas at Austin, Austin, Texas, U.S.A.; None reported.

Presently, theoretical models are available to analyze the behavior of braced girts and purlins. However, these models assume that the cross-section remains constant with no distortion. This assumption does not accurately describe the reality that exists nor the actual behavior. The tendency of these members to twist and distort may give rise to stress variations and magnitudes not accurately predicted by such models. In the present research program, a numerical model was developed which incorporates many of the factors that influence the behavior of cold-formed members. The model utilizes a semi-analytical finite element process commonly called the finite strip method. This method provides for easy incorporation of many factors into the analysis model such as distortion of the cross section, lateral elastic restraint from the sag rods, lateral elastic restraint from the sheeting, and rotational elastic restraint from the sheeting, while the computer memory and time required for the solution are minimized.

4.9 WELDED STEEL GIRDERS WITH TRAPEZOIDAL WEBS (1).

Allan Bergfelt, Bo Edlund, and Luis Leiva, Chalmers University of Technology, Division of Steel and Timber Structures, S-412 96 GOTEBORG, Sweden; Chalmers University of Technology and the Lisshed Foundation.

The buckling behavior of welded girders with corrugated webs is investigated. Two different problems are considered: Shear buckling and buckling under patch loading. In both cases the buckling behavior and the post-buckling strength of the girders are analyzed. The two problems are investigated experimentally using girders of the type that is actually utilized in Swedish construction practice. Several tests have been carried out. Both the web depth and the thickness are varied but all the test girders have the same type of corrugation.

The girders loaded in shear exhibit both local and overall buckling. In the tests the web depth has been varied in order to provoke both local buckling (small depths), global buckling (large depths) as well as interaction between these two buckling modes (medium size depth).

Girders under patch loading are investigated with the load located above different parts of the corrugation. The length of the loaded patch and the web depth were varied.

V COMPRESSION MEMBERS

5.1 BRACING AND STABILITY OF COLUMNS AND FRAMES (19).

Shien T. Wnag, Department of Civil Engineering, University of Kentucky, Lexington, Kentucky, U.S.A.; University of Kentucky.

This project deals with stability problems for columns and frames. The effects of local buckling is accounted for using the concept of effective width. Effects of various bracing combinations on the buckling loads of columns and frames are investigated. The problem is considered as a bifurcation as well as a load-deformation type problem. Both direct iterative and incremental iterative procedures are used in the analysis. In order to maintain the structural stability the required type and stiffness of bracing elements as well as the combination of different braces can be determined from the analysis. Design information can be generated for members and continuous structures with symmetric and unsymmetrical sections and for in-plane and out-of-plane buckling.

5.2 EFFECT OF SLOPING EDGE STIFFENERS ON THE CAPACITY OF COLD-FORMED SECTIONS (14).

Dimos Polyzois, Department of Civil Engineering, The University of Texas at Austin, Austin, Texas, U.S.A.; None reported.

Research to date has shown that the rigidity of edge stiffeners may significantly influence the buckling and post-buckling behavior of cold-formed steel members. While a high rigidity of edge stiffeners may result in an increase in the buckling capacity of a compression element, a low rigidity may render the compression element unstiffened, thereby significantly reducing the ultimate capacity of the member. Research, however, has primarily focused on the importance of edge stiffeners which are perpendicular to the edge stiffened elements. This situation is not representative of a large number of cross-sections in use today, where sloping edge stiffeners are very common.

The present research project deals with an experimental and theoretical investigation of cold-formed sections with sloping edge stiffeners to determine a relationship between the ultimate capacity and the angle between the edge stiffeners and the stiffened element.

5.3 LATERAL BUCKLING OF CHANNEL AND ZED SECTIONS (4).

J.M. Davies, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

The lateral buckling of channel and zed sections, and the interaction between local and global buckling is being studied by comparing: (a) experimental results, (b) general analytical results, and (c) classical buckling formulae. In this way, it is hoped to produce improved, simplified design formulae suitable for use in codes of practice.

5.4 LOCAL STABILITY PROBLEMS IN COLD-FORMED STEEL MEMBERS

Toeman Pekoz, Department of Structural Engineering, Cornell University, Ithaca, New York, U.S.A.; American Iron and Steel Institute.

Post buckling behavior of various types of plate elements and its effect on the overall behavior is being studied. The particular topics investigated include the behavior of elements with sloping edge stiffeners, unstiffened and edge stiffened elements with stress gradients. The interaction of flanges and webs is also studied.

VI BEAM-COLUMNS

6.1 FLEXURAL BUCKLING OF COLD-FORMED STEEL COLUMNS

Teoman Pekoz, Department of Structural Engineering, Cornell University, Ithaca, New York, U.S.A.; American Iron and Steel Institute.

An analytical and experimental study of the flexural buckling of singly symmetric open section columns that are locally stable according to the present AISI Specification.

6.2 DISTORTIONAL AND FLEXURAL-TORSIONAL BUCKLING OF STEEL STORAGE RACK COLUMNS (7)

Gregory J. Hancock, School of Civil and Mining Engineering, University of Sydney, Sydney, N.S.W., Australia; Australian Research Grants Scheme.

Cold-formed channels in compression can buckle in local, distortional and flexural-torsional modes depending upon the section geometry and effective lengths for flexural and torsional buckling. These modes are being investigated, mainly for storage rack columns, but also for stud walls and chords in space trusses using the Finite Strip method of structural analysis. Elastic and inelastic buckling modes are being investigated. A newly developed Spline Finite Strip analysis can account for discrete restraints along members as well as boundary conditions other than simply supported. It is currently being used to study a range of profiles in different structural systems.

VII CYLINDRICAL TUBULAR MEMBERS

7.1 RAPID INSTALLATION OF PIPELINES FOR OFFSHORE ENERGY DEVELOPMENTS (15,16)

W.F. Chen, School of Civil Engineering, Purdue University, West Lafayette, Indiana, U.S.A.; Bechtel Group, Inc.

Near-bottom bend-around of pipes is considered to be a potential innovative scheme to install flowlines in deep water ports or offshore oil platforms without the use of divers. Flowline is fabricated either on shore or using a layvessel; the flowline is then transported and positioned in a near-bottom configuration using proper buoyancy and chain package; one end of the line is pulled into a subsea base; the second end of the line is then bended around and pulled into a second subsea base.

The overall objectives of the proposed research are to devise the practical means and analytical capability necessary to achieve a satisfactory installation of the near-bottom large-angle-bend of pipeline system described above.

The development of such a capability for installation and design use of pipelines in deep water ports and offshore platforms are of prime importance for U.S. offshore energy developments. Potential future applications related to this development are for efficient design and rapid installation of pipelines in deep water offshore terminals which will transport petroleum, oils and lubricants (POL) from seafloor storage facilities to the POL storage facilities on shore.

VIII CONNECTIONS

8.1 BEHAVIOR OF BOLT GROUPS IN THIN-WALLED SECTIONS

E.R. Bryan, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

This project aims at finding the following information for bolt groups in shear under both elastic and ultimate load conditions: (a) center of rotation of bolt group, (b) whether force in bolt is proportional to distance from center of rotation, or whether the force in all bolts is the same, and (c) the slip at the bolts and hence the joint rotation. With this information it is hoped to be able to allow for the effect of semi- rigid joints in cold formed steel structures.

8.2 CONNECTIONS IN STEEL SHEETING AND SECTIONS

A.W. Toma, IBBC-TNO, P.O. Box 49, 2600 AA Delft, The Netherlands; European Economic Community-Dutch Industry.

This study involves European recommendations and treats concerning basic principles for the design of connections in thin-walled elements, design values determined by testing, and formulae for the design values for fastenings for profiled sheeting and sections. It also shows some examples from practice.

8.3 CONNECTIONS IN STEEL SHEETING AND SECTIONS

A.W. Toma, IBBC-TNO P.O. Box 49, AA Delft, the Netherlands; Cooperation between Netherlands, Great Britain, West Germany, Czechoslovakia, and Liechtenstein.

This study provides European recommendations and gives information about mechanical fasteners (blind rivets, bolts with nuts, powder actuated fasteners, screws) for use in thin-walled elements. This investigation includes two main objects: information about mechanical fasteners, and standard testing procedures for mechanical fasteners.

8.4 IMPROVEMENT OF STEEL SPOT WELD FATIGUE RESISTANCE (11)

F.V. Lawrence, Jr., Department of Civil Engineering, H.T. Corten, Department of Theoretical and Applied Mechanics, and H.H. Chen, Department of Metallurgy and Mining Engineering. University of Illinois, Urbana, Illinois, U.S.A.; American Iron and Steel Institute.

The purpose of this research program is to explore the most promising means of extending the fatigue life of spot welds through laboratory tests and predictions using the initiation-propagation model for fatigue life, which estimates the fatigue life of spot welds. Work is being carried out in three categories: (1) fatigue testing of nominal and specially treated spot welds under constant and variable load amplitudes, (2) material characterization and metallurgical studies relating to the physical phenomena, and (3) further refinement of the initiation-propagation analytical model for fatigue life prediction.

IX SHEAR DIAPHRAGMS

9.1 PRE-ENGINEERED STEEL BUILDING DIAPHRAGMS USING SELF DRILLING SCREWS

L.D. Luttrell, Department of Civil Engineering, West Virginia University, Morgantown, West Virginia, U.S.A.; STRAN/WVU

This project addresses the strength and stiffness of lighter gage steel diaphragms, screw connected, over Z and C-shaped purlines following the design models developed for the Steel Deck Institute. It includes screw responses, both in strength and stiffness, for several screw sizes in 24, 26, and 28 gage material. Corner and rake trim closure devices are studied.

X CORRUGATED SHEETS AND FORMED PANELS

10.1 BENDING STRENGTH OF HIGH STRENGTH COLD-FORMED CORRUGATED PANELS (8)

Asadul H. Chowdhury and James L. Jorgenson, Department of Civil Engineering, North Dakota State University, Fargo, North Dakota, U.S.A.; Wedg-Cor, Inc.

The thin cold-formed steel straight panels are used in the construction of metal buildings. The metal panels serve as both a covering of the building and as a structural frame. These panels as used in the metal buildings have h/t ratio in excess of 400. However, the AISI Code limit for h/t ratio is only 200. Only limited amount of experimental evidence is available dealing with the bending strength of straight panels having h/t ratio values between 200 and 350. The results of those studies show that the AISI Code criteria for allowable bending stress in the web of the straight panel is extremely conservative when applied for h/t values above the 200 limit.

The present experimental investigation proceeds one step further in that it treats the bending strength capacity of 26 gage cold-formed steel straight panels with h/t ratio of 475. The average yield strength of the steel is 96.9 ksi (667.7 MPa) and the average elongation at rupture is 2.68%. A typical test specimen is 7 ft (2.1 m) wide, 14.5 ft (4.4 m) long and consists of three corrugated panels connected side by side with an overlap on the bolt lines.

10.2 STABILITY OF CORRUGATED SECTIONS

Raymond L. Cary, Structural Research Division, Armco, Inc. Middletown, Ohio, U.S.A.; Armco, Inc.

An experimental program of flexural and axial compressive tests is being conducted on arc/tangent corrugated steel profiles to determine influence of corrugation parameters on profile stability. Arc inside radius/thickness ratios varied from 3.7 to 34.1. Tangent length/ thickness ratios varied from 4.4 to 37.0. Tensile yield strengths varied from 35 to 50 ksi (241.2 to 544.6 MPa).

Flexural tests have been conducted. Corrugated specimens were subjected to constant moment at midspan and plastically strained until the profile buckled. Buckled elements were noted. Critical buckling strains and maximum moment capacity were calculated. Strain and moment capacities will be related to corrugation parameters.

Stub column tests are underway.

Design guidelines will be developed to help designers prevent premature buckling of corrugated profiles.

XI PLATE STRUCTURES

11.1 ANALYTICAL AND EXPERIMENTAL INVESTIGATIONS OF STIFFENED PLATES (9)

V. Kalyanaraman and H.B. Aravind, Department of Civil Engineering, Indian Institute of Technology, Madras 600036, India; Aeronautical Research and Development Board, Govt. of India.

Stiffened panels may be subjected to several types of loadings, either acting separately or in combination. Presence of initial imperfections and residual stresses due to cutting and welding process cause nonlinear behavior even before applied stress is in the range of material nonlinearity. Many studies have indicated that local and overall buckling and interaction of local and overall buckling are affected by initial imperfection and residual stress.

The objective of present investigation is to develop a computer program based on nonlinear finite strip method. The program will be able to consider the combined effect of (1) geometric initial imperfection and residual stress, (2) local buckling of plates, (3) overall buckling of panels, (4) interaction of different modes of buckling, (5) nonlinear stress strain behavior of material, and (6) effect of lateral load on the panels.

It is also planned to carry out experimental investigations on stiffened plates subjected to inplane and lateral loads to study (1) the effect of initial imperfections and residual stress on stiffened plate strength, (2) influence of different types of stiffener, and (3) different modes of buckling and their interaction.

XII SHELL STRUCTURES

None

XIII COMPOSITE CONSTRUCTION

13.1 DESIGN OF SANDWICH PANELS WITH FOAM CORES

J.M. Davies, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

Theoretical and experimental investigations are being carried out concerning many aspects of sandwich panel design including (1) general methods of analysis, (2) determination of the wrinkling load at an internal support, and (3) material properties.

13.2 "REAL-WORLD" FACTORS AFFECTING THE DESIGN OF COMPOSITE STEEL/CONCRETE FLOOR SLABS

L.D. Luttrell, Department of Civil Engineering, West Virginia University, Morgantown, West Virginia, U.S.A.; The Steel Deck Institute.

The intent of this project, substantially complete, has been to determine the effects of slab/panel geometry (including web size, panel shape, and embossment configurations) on the strength of composite slabs. Further, its aim has been to develop a viable predictive equation for strength leaving testing in the more appropriate position of confirming the response. The several "real-world" effects such as rolling loads v. concentrated shears are under study along with reinforcement layout and methods of panel attachment.

XIV STRUCTURAL SYSTEMS

14.1 DESIGN AIDS AND DESIGN PROCEDURES FOR HOLLOW STRUCTURAL SECTION STEEL TRUSSES (2)

J.A. Packer, Department of Civil Engineering, University of Toronto, Toronto, Ontario, Canada; Comite International pour le Developpement et l'Etude de la Construction Tubulaire/Canadian Steel Construction Council.

Design aids are presented for welded Hollow Structural Section (HSS) joints in single chord planar trusses, having rectangular hollow section chord members and subject to predominantly static loading. The steel sections can be either cold-formed, cold-formed stress-relieved or even hot-formed. The design aids are based on complex joint design recommendations recently proposed by CIDECT and the International Institute of Welding, which are considered to represent the current state-of-the-art. These recommendations are explained and adapted by the authors to be compatible with CAN3-S16.1-M78: Steel Structures for Buildings - Limit States Design, and are consistent with current Canadian engineering practice. A manual design method is given which relies on 6 design charts to simplify the joint strength (or efficiency) calculations and aid in the selection of members. In addition, an interactive micro-computer program for the design of HSS welded trusses is also presented. Design examples are also provided.

14.2 PARAMETERS AFFECTING THE BEHAVIOR OF METAL BUILDING ROOF SYSTEMS UNDER GRAVITY LOADING (12)

Thomas M. Murray, Department of Civil Engineering, University of Oklahoma, Norman, Oklahoma, U.S.A.; Metal Building Manufacturers Association and American Iron and Steel Institute.

Development of prediction equations for required restraint forces in Z-purlin supported conventional metal building roof systems under gravity loading with full-scale and quarter scale experimental verification.

14.3 RESTRAINT REQUIREMENTS FOR Z-PURLIN SUPPORTED STANDING SEAM ROOF SYSTEMS - A PILOT STUDY

Thomas M. Murray, Department of Civil Engineering, University of Oklahoma, Norman, Oklahoma, U.S.A.; Metal Building Manufacturers Association.

The primary objective of this study is to determine if scale models can be used to study the behavior of standing-seam roof systems. Particular emphasis is given to the development of a suitable scaled panel-to-purlin clip. Full-scale connection restraint tests will be used to develop prototype data.

14.4 ULTIMATE STRENGTH OF SPACE TRUSS STRUCTURES COMPOSED OF MEMBERS SUBJECTED TO LOCAL AND OVERALL BUCKLING (20)

Shien T. Wang, Department of Civil Engineering, University of Kentucky, Lexington, Kentucky, U.S.A.; University of Kentucky.

This project deals with ultimate strength and instability problems of three dimensional truss systems. The effects of local buckling of component plates and column buckling on the overall buckling strength of the truss system are considered. The post-buckled and post-yielded strength and stiffness of the compression and tension members are accounted for in the analysis. To account for the nonlinearities involved, two numerical approaches are used in the analysis, i.e. direct iterative procedure and incremental iterative procedure. The analysis traces the sequence of local and member buckling until eventual failure of the whole structure. The results shed light on the failure mechanism of recent collapses of several major space truss structures and procedure to take in order to avoid such problems in the future.

XV COMPUTER AIDED DESIGN

15.1 COMPUTER AIDED OPTIMUM DESIGN OF STIFFENED PLATES

V. Kalyanaraman and V. Baburaj, Department of Civil Engineering, Indian Institute of Technology, Madras, 600036, India; Aeronautical Research and Development Board, Govt. of India.

The minimum weight design of a stiffened plate subjected to various loading conditions, such as axial compression, shear etc., under the constraints of local and post buckling strength at component level and system level have to be carried out. The constraints at the component level involve the different mode of elastic buckling of stiffener and buckling and post-buckling strength of panel bays individually. At the system level constraints involve the different mode interaction failure. It is proposed to carryout an extensive study of optimum design of stiffened plate structures using both conventional and advanced composite materials. The work therefore involves (1) development of a design procedure that includes the post local buckling strength effect of residual stress and initial imperfections based on the information currently available in literature (2) development of a non-linear mathematical programming software for use in the optimum design and, (3) development of computer aided optimum design software for stiffened plates. The relative merits of various types of stiffeners would be considered.

XVI DYNAMIC BEHAVIOR OF STRUCTURES

16.1 SEISMIC RESPONSE OF FRAMES HAVING THINWALLED COLUMNS (17)

S. Sridharan, Department of Civil Engineering, Washington University, St. Louis, Missouri, U.S.A.; National Science Foundation.

The proposed research deals with the interaction of P-Δ effects associated with overall bending and local buckling in thinwalled columns of plane framed structures, under conditions of seismic excitation. A new analytical model is proposed which has the necessary degrees of freedom built into it to describe not only the overall behavior of the frame but also the local buckling deformation. In particular, the model accounts for: the flexural-torsional modes of vibration which can be triggered because of the unsymmetric distribution of effective stiffness caused by local buckling; the appearance of secondary local modes as a result of interaction of overall bending with the primary local mode; and the nonlinear modal coupling between the otherwise uncoupled overall buckling modes of columns having symmetric sections, caused by local buckling. Advantage is taken of the finite strip technique to produce simply the relevant local buckling fields as well as the associated postbuckling displacement fields. A set of coupled nonlinear Lagrangian equations of motion in terms of the degrees of freedom are derived and solved in time domain using a numerical procedure to produce the dynamic response. The influences respectively, of initial imperfections, slenderness of 'stiffened' and 'unstiffened' constituent plate elements and the ratio of overall critical load of the frame and the local critical load of the column members would be investigated by parametric studies.

16.2 STATIC AND DYNAMIC ANALYSIS OF LOCALLY BUCKLED FRAMES

George E. Blandford, Department of Civil Engineering, University of Kentucky, Lexington, Kentucky, U.S.A.; None reported.

Research activities on steel frame structures deal with the development of a computer-aided-design program for light-gage steel structures subjected to earthquake excitation. Since earthquake excitation can induce severe stresses into the structure, the incorporation of inelastic member response and secondary moments caused by large displacements is essential for a proper and economical design. Furthermore, local buckling in the compression flanges and webs included. Previous analysis/design of light-gage steel framed structures has been primarily limited to static gravity loading with no consideration of potential earthquake induced stresses.

XVII RELIABILITY ANALYSIS

17.1 LOAD AND RESISTANCE FACTOR DESIGN FOR COLD-FORMED STEEL MEMBERS (5)

Wei-Wen Yu, Department of Civil Engineering, University of Missouri-Rolla, Rolla, Missouri and T.V. Galambos, Department of Civil Engineering, University of Minnesota, Minneapolis, Minnesota, U.S.A.; American Iron and Steel Institute.

The tentative recommendations on the load and resistance factor design of cold-formed steel structural members and connections have been developed on the basis of the first-order probability theory. The newly developed method has been compared with the allowable steel design method.

17.2 RELIABILITY OF SPOT WELDS IN COLD-FORMED STEEL MEMBERS

Andrzej S. Nowak, Department of Civil Engineering, University of Michigan, An Arbor, Michigan, U.S.A.; Bechtel Power Corporation.

Cold-formed channels are joined by means of spot welds to form various configurations. They are used in typical electrical cable and conduit supports, also in power plants. The present design procedures follow AISI specifications, which gives the allowable load per spot weld as a function of the thickness of connected plates. Tests were carried out to establish the distribution of spot weld capacity. It has been found that the strength strongly depends on technology of welding. It is recommended to review the AISI provisions and specify special allowable loads for spot welds connecting cold-formed channels. The allowable loads could vary depending on type of connection (back-to-back, side-to-side, side-to-back) and technology of welding (degree of correlation between adjacent welds).

XVIII FIRE RESISTANCE RATINGS

None

XIX TEXTS, SPECIFICATIONS AND COMMENTARIES

19.1 STUDIES FOR THE 1986 AISI SPECIFICATION

Teoman Pekoz, Department of Structural Engineering, Cornell University, Ithaca, New York, U.S.A.; American Iron and Steel Institute.

Studies on the development of the 1986 AISI Specification include the reduction of the conclusions of several research projects carried out at

Cornell University in the past 15 years into design provisions. The features studied include unified approaches to the treatment of plate elements and members. The unified approach for plate elements involves the use of a generalized effective width concept for stiffened, unstiffened, perforated elements, webs, elements with edge or intermediate stiffeners. The approach for members covers locally stable and unstable columns, beams and beam-columns. The elimination of the Q method used presently to account for local buckling effects is being studied. Approaches for locally stable and unstable singly symmetric beam-columns of open section are being developed.

XX OTHERS

20.1 COMPARISON OF NATIONAL CODES OF PRACTICE FOR DESIGN IN LIGHT GAGE STEEL

E.R. Bryan, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

This undergraduate project consists of carrying out design examples according to the British Codes (1) Addendum No. 1 to BS 449 and (2) the draft BS 5950 Part 5, and to the American AISI Specification.

Points of difficulty in understanding the codes are noted, and differences between the codes for the particular examples are shown up.

20.2 GENERAL METHODS OF ANALYSIS FOR COLD-FORMED STEEL MEMBERS AND ASSEMBLIES

J.M. Davies, Department of Civil Engineering, University of Salford, Salford, U.K.; None reported.

For the second-order analysis of thin-walled open sections, a finite element with seven degrees of freedom has been developed which is capable of modeling all the global buckling modes. With the aid of a suitable transformation matrix, this is being used to investigate the second-order behavior of assemblies of cold formed sections.

For the general analysis of cold-formed sections, including the influence of local buckling and cross-sectional distortion, the "generalised beam theory" is being implemented using both finite difference and finite element techniques.

XXI CONCLUSIONS

This survey shows that the reported research projects include both basic and applied research, the majority of which is being carried out at universities. The primary sponsoring organizations are governments, industries, and universities.

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