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Abstracts of Conference Papers

During October 18-19, 1994 the 12th International Specialty Conference on Cold-Formed Steel Structures will be held in St. Louis, Mo. The following are simplified abstracts or brief summaries of the 43 papers to be presented and discussed at the conference:

1."Local Buckling of Stiffened and Unstiffened Elements Under Nonuniform Compression," by V. Kalyanaraman and P. Jayabalan.

Thin plates subjected to linearly varying inplane compression in one direction may undergo local buckling before failure. An analytical procedure is presented for evaluating the local buckling strength of unstiffened and stiffened elements.

2."The Compressional Behaviour of Perforated Elements," by J. Rhodes and F.D. Schneider.

The behaviour of stub columns with a series of different perforation patterns is examined on the basis of tests. The tests concentrate on plain channel cross sections with perforation layouts systematically varied to examine the effects of perforation position, dimensions and number on the section performance. The application of existing cold-formed steel design codes to perforated members is examined on the basis of comparison with the tests, and various modifications to the design codes are considered to take perforations into account.

3."Strength of Stiffened Plates With Openings," by M. Mahendran, N.E. Shanmugam and J.Y.R. Liew.

The load-deflection and ultimate strength behaviour of longitudinally stiffened plates with openings was studied using a second-order elastic post-buckling analysis and a rigid-plastic analysis. Comparison with experimental results shows that satisfactory prediction of ultimate strength can be obtained by this simple method. Effects of the size of opening, the initial geometrical imperfections and the plate slenderness ratio on the strength of perforated stiffened plates were also studied.

4."Experiments on Lipped Channel Flexural Members," by M.E. Moreyra and T. Peköz.

A series of tests was conducted on lipped channel flexural members to study the behavior of edge stiffened elements. The details and the results of these tests as well as tests by others are discussed in this paper. All the test results are compared with those predicted by the AISI Specification.

5."Finite Element Studies on Lipped Channel Flexural Members," by M. E. Moreyra and T. Peköz.

This paper is second in a series of three papers describing the research sponsored by the American Iron and Steel Institute. Physical test results described in the first paper combined with the finite element solution parametric studies described in this paper were used in the third paper to develop improved design procedures for edge stiffened elements.

6."A Design Procedure for Lipped Channel Flexural Members," by M.E. Moreyra and T. Peköz.

This paper is third in a series of three papers describing the research sponsored by the American Iron and Steel Institute. Physical test results described in the first paper combined with the finite element solution parametric studies described in the second paper were used in this paper to develop improved design procedures for edge stiffened elements.

7."Study on the Load-Bearing Capacity of Cold-Formed Sigma Purlins," by M. Laine and P. Mäkeläinen.

Experimental investigations conducted on the structural behaviour and ultimate load carrying capacity of cold-formed sigma purlins are reported. Three different purlin systems were investigated. Analytical considerations for modelling the cross-sectional behaviour of the sigma purlin itself and the local deformation of the connection at supports are carried out mainly according to the draft of Eurocode 3. Test results are used to compare and to confirm the calculation models based both upon elastic and plastic behaviour of the purlin. A new plastic design proposal is presented for multiple span sigma purlins.

8."The Analysis of Restrained Purlins using Generalised Beam Theory," by J.M. Davies, C. Jiang and P. Leach.

This paper extends the use of Generalised Beam Theory to consider the behaviour of a cross section which is elastically restrained continuously along its

Abstracts Continued

length. The paper illustrates how the basic equations of GBT can be used to calculate the buckling load of an elastically restrained cross section taking account of interaction between the different buckling modes. Using this estimate of the buckling load, an assessment of the collapse load of a restrained section can be made using the interaction formulae of Eurocode 3 to allow for both buckling and yielding.

9."Comparison of a Non-Linear Purlin Model With Tests," by C.J. Rousch and G.J. Hancock.

A non-linear elastic analysis has been developed for determining the lateral deflections of, and stresses in, the unconnected flanges of simply-supported and continuous channel and Z-section purlins screw-fastened to sheeting and subjected to either wind uplift or gravity loading. The analysis incorporates a model, based on a combination of those developed by Pekőz and Soroushian, and Thomasson, which depicts the unconnected purlin flange as a beam-column. In this paper, results from vacuum rig tests on continuous Z-section purlins screw-fastened to sheeting and subject to simulated wind uplift and gravity loading are compared with the analysis.

10."Reference Section Method for Local Web Buckling," by T.K. Sooi, R.L. Serrette, and T. Pekőz.

The present AISI effective width approach for determining flexural section capacities of sections with slender webs requires an iterative approach. A simplified method, called the Reference Section Method or RSM, which eliminates the need for iteration is presented and discussed. To demonstrate the applicability of the RSM, parametric study was performed on channel joist/rafters (MSMA sections). The capacities of the sections predicted using the RSM are compared to the AISI predicted capacities.

11."Bending and Shear Behavior of Web Elements With Openings," by M.Y. Shan, R.A. LaBoube, and W.W. Yu.

Cold-formed steel C-sections with web openings are frequently used as wall studs and floor joists in both commercial and residential construction. To quantify the degrading effect of a web opening, a study has been conducted at the University of Missouri-Rolla to investigate the loading conditions of bending, shear, web crippling and the combinations thereof. This paper summarizes the results of an experimental study of the behavior of combined bending and shear using 68 beam specimens. It is concluded that the interaction equation employed by the AISI Specification will provide an adequate strength prediction, provided that the individual shear capacity is modified to account for the influence of the web opening.

12."Perforated Webs Subjected to End-One-Flange Loading," by J.E. Langan, R.A. LaBoube, and W.W. Yu.

A study of structural behavior was conducted and a design equation was developed that accounts for the degradation in web crippling capacity caused by web openings for unreinforced single web cold-formed steel flexural members subjected to the End-One-Flange (EOF) loading condition. The research findings enable the current EOF design provisions for sections without web openings to be modified by a reduction factor equation to obtain the web crippling capacity for sections with web openings.

13."Flexural Capacity of Continuous Span Standing Seam Panels: Gravity Load," by R.L. Serrette and T. Pekőz.

The standing seam panel is one of the most practical and economical roofing systems developed in recent years. A design method was previously suggested for estimating the distortional buckling strength of the outstanding leg of a single simply supported standing seam panel. In this paper, an approximate method is presented for estimating the capacity of a system of interconnected continuous span standing seam panels. Experimental results for three full-scale continuous span tests and one full-scale simple span test show that the approximate method provides a relatively accurate estimate of the maximum capacity for a system subject to gravity load.

14."Ultimate Behaviour of Trapezoidal Steel Sheets in Bending," by R. Landolfo and F.M. Mazzolani.

A systematic analysis of existing trapezoidal steel sheets commonly used in the market is performed in order to investigate the ultimate bending behaviour of standard trapezoidal sheets. The complete investigation has been developed both from theoretical and experimental points of view. In this paper, the description of the experimental techniques, the numerical simulation of the obtained results as well as the exploitation of these data in order to check the codified design rules are reported.

15."Multiple Stiffened Deck Profiles," by R.P. Papazian, R.M. Scnuster and M. Sommerstein.

CAN/CSA-S 136-M89 and the AISI Specification on Cold-Formed Steel Design use different methods to determine the effective width of multiple stiffened compressive elements when no local buckling in the sub-elements occurs. Both methods replace the multiple stiffened element with a flat plate element centered at the neutral axis of the multiple stiffened element. The methods differ in assigning an equivalent thickness to the straight line element. In this paper, experimental data is compared with the predicted values of each method and conclusions are drawn from these comparisons. Representative hat sections were subjected to uniformly distributed loads using a vacuum chamber. Profiles with one, two, three and four intermediate stiffeners were tested, using three material thicknesses for each configuration of stiffeners.

16."Buckling Behaviour of Cold-Formed Thin-Walled

Abstracts Continued

Members by Spline Finite Strip Analysis," by J. Lindner and Y.L. Guo.

Local, distortional and overall buckling (including overall flexural buckling and overall flexural-torsional buckling) behaviour of cold-formed thin-walled columns is presented which is based on an inelastic spline finite strip analysis. The columns are loaded centrally at the ends. The increment of yield stresses in the corner area due to cold-forming work, together with a more real stress-strain curve of material, that exhibits continuous strain hardening for the stress above the proportional limit of material, are involved in the analysis. Numerical results are obtained which reveal that the inelastic distortional buckling behaviour is very important.

17."Elastoplastic Large Deflection Analysis of Cold-Formed Members Using Spline Finite Strip Method," by S.L. Chen, S.F. Li and S.F. Fang.

The elastoplastic large deflection behaviour of cold-formed members is analysed by a nonlinear spline finite strip method. The method is developed using the principle of virtual work, based on the total Lagrangian description. It is used to deal with problems of geometric and material nonlinearity. The effect of arbitrary initial imperfections is taken into consideration. The influence of cold-bending residual stress on the local and overall behaviour of cold-formed lipped angle columns is also investigated especially. The numeric examples show that the method possesses such advantages as fewer degrees of freedom, fine continuity, good boundary adaption, quick computation speed and high accuracy.

18."Behaviour of Cold-Formed SHS Beam-Columns," by R.M. Sully and G.J. Hancock.

This paper describes a test programme conducted into the behaviour of cold-formed, compact square hollow section beam columns. The tests were conducted in a test rig capable of applying load and moment in a constant ratio. The test specimens were pin-ended specimens loaded, with varying load/moment ratios, at two different ratios of end moment. The results of the tests were simulated using a finite element programme. This finite element programme was used to find maximum second order elastic moments, for the section tested, at varying ratios of end moment. The results of this numerical investigation are compared with the relevant interaction design rules from Australian Standards AS4100 and the AISC-LRFD specification.

19."Stub Column Study Using Welded, Cold-Reduced Steel," by L.R. Daudet and K.H. Klippstein.

The primary goal of the subject study was to investigate the behavior and load capacity of stub columns using cold-reduced, low-ductility steel versus un-reduced, normal-ductility steel. Specimens that were cold-reduced were also welded transversely across the entire stud cross section. This study also yielded data with regard to the axial performance of welded studs. In addition, since stub columns were punched and unpunched, further conclusions can be drawn about the effect of a weld located at a web perforation.

20."Cold-Formed Steel Sections for Transmission Towers," by D. Odaisky, D. Polyzois, and G. Morris.

A research project was carried out at the University of Manitoba to examine the axial compressive load capacity of a number of cold-formed shapes suitable for transmission tower construction. Test parameters included: five different cross-sections, two steel grades, three different slenderness ratios, and three temperature levels. Specimens were tested in setups designed to simulate end conditions representative of actual web members by loading through single legs bolted to gusset plates. Results of 189 tests were compared to ultimate loads obtained from the Canadian Standards, CAN/CSA-S136-M89 and CAN/CSA-S37-M86, as well as to loads predicted by the ASCE Manual 52 and the ECCS Recommendations for Angles in Lattice Transmission Towers.

21."Further Studies of Composite Slab Strength," by A.S. Terry and W.S. Easterling.

The results to date of a research program focusing on the strength of composite slabs are described. Full-scale experimental slab tests are compared to strengths calculated using the Steel Deck Institute Composite Deck Design Handbook. Based on the comparisons, recommendations are made for modifications to the calculation procedures.

22."Review of Concepts Concerning Bond of Steel Decking," by M. Patrick and R. Bridge.

It is well established that bond between deformed reinforcing bars and concrete is produced by three distinct actions: chemical adhesion, friction, and mechanical interlock. However, researchers of composite slab behaviour do not generally agree on the actions which produce bond between steel decking and concrete, and the concepts they have developed in this regard are reviewed.

23."Behavior and Failure Mechanism of Composite Slabs," by J.J.R. Cheng, M.C.H. Yam and E.B. Davison.

The behavior of a composite slab using a 636 deck profile was investigated experimentally. Twenty-three one-way slab tests and twenty-four pull-out tests were

Abstracts Continued

performed. It was found that the behavior and shear bond load of the composite slab were significantly affected by the depth of the embossment shear key. The average shear stress from the pull-out tests was generally lower than that of the one-way slab tests due to a lack of the transverse load effects which influenced the frictional resistance between the concrete slab and the steel deck.

24."Slip and Separation at Interface of Composite Slabs," by L. An and K. Cederwall.

Resistance of composite elements at the sheet-concrete interface was determined from a small-scale test. The influence of resistance at the interface, especially the vertical resistance, on the behavior of composite slabs was studied by a finite element method. The results showed that the horizontal shear resistance affected greatly the capacity of the composite slabs. However, the vertical resistance did not influence much the capacity and it can be neglected in the analysis.

25."Tests of Thin-Walled Concrete-Filled Steel Tubes," by M.D. O'Shea and R.Q. Bridge.

Concrete filled tubes are likely to be economical with the use of very high strength concretes and thin-walled steel tubes. The strength of the steel tube is affected by local buckling effects which may also influence the confinement to the concrete infill. This paper describes the initial tests of an experimental program to determine the effects of local buckling on concrete filled tubes. Measurements of geometric properties including imperfections, material properties of the concrete and steel including residual stresses, and the strain and axial shortening behaviour of the tubes under load are presented. The test equipment and procedures developed for the program are described. The use of an effective area approach to account for local buckling of the tube wall is considered and compared with the test results. The significance of local buckling and concrete confinement is discussed.

26."Local Buckling of Filled Sections," by H.D. Wright.

The buckling capacity of plates in contact with a rigid medium is greater than that for free plates. Such plates occur in sections filled with a suitably stiff material. Classical analysis is used to compare restrained and free plates.

27."Core Loaded Thin-Walled Sleeved Column System," by S. Hariharan, K. Mahadevan, and V. Kalyanaraman.

In conventional columns, the load carrying capacity is governed by the yield strength of the material and its buckling strength. In practice the strength of conventional compression members is less than both the yield strength and Euler buckling strength due to the effects of imperfections, residual stresses, etc. In this paper behaviour of a novel patented concept, referred to as core loaded thin-walled sleeved column system, is discussed.

28."Axial Load Capacity of Sheeted C and Z Members," by N. Glaser, R. Kaehler and J. Fisher.

An equation is developed for calculating the axial load capacity of C and Z shaped members used in roof or wall systems. The equations were determined to be valid for through fastened metal decking but not standing seam roof decking.

29."Design of a Purlin System," by J.M. Davies, C. Jiang and D. St Quinton.

This paper is concerned with the design of cold-formed steel structural members which span between the frames of a building and carry cladding which is usually either single- or double-skin profiled metal sheeting or a sandwich panel. It is shown that, in the present state-of-the-art, a design procedure based entirely on calculation, while taking into account such practical factors as restraint from alternative cladding systems and distortion and partial plasticity at internal supports, is now feasible.

30."Tests of Purlins with Concealed Fixed Sheeting," by G. Hancock, M. Celeban, and C. Healy.

A test program on purlin-sheeting systems with concealed fasteners has been performed at the University of Sydney in a vacuum test rig. The test rig used a conventional vacuum box to simulate wind uplift. Z-section purlins were tested in three span lapped configurations, and as simple spans. The test purlins were supported by a range of bracing (bridging) members ranging from zero to two braces per span. In addition, a range of section slenderness values was used so as to precipitate both local buckling and yielding failures in the section. The purpose of the paper is to compare the test results with design loads in the Australian Standard AS 1538-1988 based on a flexural-torsional buckling analysis.

31."An Innovative Cold-Formed Floor System," by J.R. Hillman and T.M. Murray.

A cold-formed steel floor system has been proposed and tested. The system is shallower and weighs less than conventional systems. The system consists of deep long-span deck sections, a transverse shallow deck, "stand-off" shear connectors, and a thin concrete slab. Only standard engineering calculations are required for design. A prototype bay was designed and tested. The system performed as predicted to a loading of 65 psf (3.2 kN/m^2) and was found to be satisfactory with regard to floor vibration serviceability.

32."Analysis and Design of Continuous Sandwich Beams," by P. Hassinen and L. Martikainen.

Sandwich panels are composed of two thin face layers and a lightweight core between them. Panels are used to carry large bending moments and axial forces, which capacity is reduced, if imperfections, for example initial deflec-

tions or transverse loads, appear in the face layers. At intermediate supports the panel is stressed by a high bending moment, and in addition, by a concentrated lateral support reaction. The strength against the simultaneous bending moment and support reaction depends on the bending stiffness and on the bending and buckling strength of the face and on the compressive strength of the core. The paper studies factors having influences on the behaviour and on the failure modes of multispan sandwich panels. Also proposals to estimate the strength at the serviceability and at the ultimate limit states are presented.

33."The Lateral Torsional Buckling Strength of Cold-Formed Stainless Steel Beams," by P.J. Bredenkamp and G.J. van den Berg.

The findings of an investigation of the lateral torsional buckling strength of cold-formed stainless steel beams are reported in this study. The sections under consideration are cold-formed lipped channel sections spot-welded back to back to form doubly-symmetric lipped I-beams. The beams were fabricated from a modified AISI Type 409 stainless steel, designated Type 3CR12 corrosion resisting steel. The purpose of this study is to compare the experimental lateral torsional buckling strengths of doubly-symmetric beams to the theoretical predictions proposed by the ASCE Specification for the Design of Cold-Formed Stainless Steel Structural Members. It was concluded that an acceptable prediction of beam strength may be obtained through the use of the tangent modulus approach adopted in the ASCE specification.

34."Web Crippling of Stainless Steel Cold-Formed Beams," by S.A. Korvink and G.J. van den Berg.

The results of an investigation on the web crippling strength of cold-formed stainless steel channel sections are presented in this paper. The steels under consideration are AISI Type 430 stainless steel and a modified AISI Type 409, designated Type 3CR12 corrosion resisting steel. Experimental results were compared with the theoretical predictions given in the 1991 edition of the ASCE Specification for the Design of Cold-Formed Stainless Steel Structural Members. It was concluded that the experimental results compare reasonably well with the theoretical predictions.

35."The Strength of Partially Stiffened Stainless Steel Compression Members," by Y. Buitendag and G.J. van den Berg.

The instability of partially stiffened stainless steel compression members due to local buckling of the flange element has not been studied before. In this investigation the critical local buckling and post-buckling behaviour of cold-formed partially stiffened stainless steel compression elements is studied. It is concluded that a plasticity reduction factor should be used to evaluate the critical local buckling stress as well as the effective width to calculate the ultimate capacity of partially stiffened stainless steel compression members.

36."Stainless Steel Tubular Joints - Tests and Design of X- and K-Joints in Square Hollow Sections," by K.J.R. Rasmussen and B. Young.

The paper describes a test program on welded stainless steel X- and K-joints fabricated from square hollow section brace members and chords. The X-joints were tested in compression and tension using different ratios of brace width to chord width. The K-joints were tested by varying the ratio of brace width to chord width, the angle between chord and brace members, and the preload applied to the chord. A total of 23 tests were performed. Design rules are proposed for X- and K-joints by adopting the rules of the CIDECT Recommendations for carbon steel tubular structures and replacing the yield stress in these recommendations by a proof stress.

37."Stainless Steel Tubular Joints - Tests and Design of X- and K-Joints in Circular Hollow Sections," by K.J.R. Rasmussen and A.S. Hasham.

The paper describes a test program on welded stainless steel X- and K-joints fabricated from circular hollow section brace members and chords. The X-joints were tested in compression and tension using three different ratios of brace diameter to chord diameter. The K-joints were tested using three different ratios of brace diameter to chord diameter and three different angles between chord and brace members. A total of 15 tests were performed. Design rules are proposed for X- and K-joints by adopting the rules of the CIDECT Recommendations for carbon steel tubular structures and replacing the yield stress in these recommendations by a proof stress.

38."Pallet Racking Using Cold-Reduced Steel," by J.M. Davies and J.S. Cowen.

In this paper, the justification for the use of low-ductility steel is taken a stage further by describing a series of tests on racking components made from both cold-reduced steel and an equivalent hot-rolled steel of similar yield stress but much greater ductility. It is shown that the use of hard steel has no adverse effect on performance. The paper concludes by describing a test to failure of a full scale rack structure fabricated using components made from cold-reduced steel.

Abstracts Continued

39."Seismic Response of Single-Storey Steel Buildings," by R. Tremblay and S.F. Stiemer.

Nonlinear time step dynamic analyses have been performed on 24 rectangular single-storey steel framed buildings including a metal roof deck diaphragm and steel bracing bays along their exterior walls. Based on these results, preliminary design guidelines have been proposed for predicting the deformations, moments and shear forces in roof diaphragm as well as for confining inelastic action in the vertical bracing elements.

40."Fatigue Behaviour of Cold-Formed Steel Sections," by S.K. Hassan, D. Polyzois, and G. Morris.

In the expected life span of a transmission tower, the members are subjected to a large number of alternating wind applications. Fatigue behaviour due to repeated loading must therefore be considered in design. This paper presents the fatigue-test results for 52 cold-formed steel members. The results obtained can be used to establish additional guidelines for fatigue design of cold-formed steel sections.

41."Residual Stresses in Cold-Formed Steel Sections," by G. Roy, M.A. Mohamedien, and D. Polyzois.

Initial or residual stresses are considered one of the major factors that affect the design of the cold-formed steel sections, since they could reach 50% of the yield stress of the material. As part of a comprehensive experimental program on the use of cold-formed steel sections in transmission towers, an investigation on the magnitude and distribution of residual stresses in cold-formed steel sections was undertaken. The study involved 83 tests using two nondestructive methods, and two destructive methods, to determine the magnitude and distribution of residual stresses. The paper summarizes the results from this investigation and outlines a number of implications for the design of cold-formed sections.

42."Behavior of Connections between SHS Columns & W-Section Beams," by K.S. Kim, J.S. Lee, and Y.B. Kwon.

Connections between SHS (Square Hollow Section) columns and W-section beams are generally fabricated by welding with or without endplates in the factory. In this paper, a series of connection tests joining SHS column and W-section beam were executed and the test results compared with theoretical values. A method to utilize nonlinear moment-rotation relations of beam-to-column connections in steel framed structures is proposed. For the problem of contact in endplate-type connections, a simple and efficient method is also introduced.

43."Light-Gauge Engineering in Today's Marketplace - The Challenges," by G. Farach and R.C. Grupe Jr.

Light-gauge steel has tremendous potential in the construction industry. It is a material which affords more carrying capacity per less weight. Thus less material needs to be used which leads to a reduction in labor and subsequent reduction in cost. Light-gauge steel is a durable, recyclable product, environmentally friendly in keeping with today's concern for the world around us. Some of the technology already exists and only needs to be adapted to steel. In some cases the technology itself has yet to be developed. If we are content with today's mode of business practice, we will lose tomorrow's opportunities through stagnation. The challenge is to expand our horizons and increase the viability of the light-gauge steel framing industry.

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