Section J

COLD FORMED SECTIONS

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This paper is the result of deliberations of the Society's Study Group for the Seismic Design of STEEL STRUCTURES.

1. SCOPE AND CONTENTS

1.1 Scope

This paper gives recommendations to assist designers in the seismic design of structures in which the primary structural system is composed of cold formed members. The primary seismic resisting system or systems may be of cold formed sections or hot rolled sections depending on the inelastic ductility demand.

1.2 Contents

2. INTRODUCTION AND INELASTIC BEHAVIOUR

2.1 Introduction

For over 20 years the use of cold formed members has been common for secondary structural systems such as the purlins and girts used in industrial buildings. However the use of cold formed members for the primary structural system has been comparatively rare. This situation will soon be altering as the planned production of larger cold formed sections by N.Z. Steel Ltd. and development of efficient jointing systems will make the complete construction of industrial buildings from cold formed sections economical.

Cold formed sections are not generally considered suitable for use in structures subject to seismic attack. The sections are formed by cold forming flat sheets of mild or low alloy steel into a desired section shape. The thickness of sheet used is limited by the cold forming process to considerably less than that used in hot rolled sections, hence a cold formed section of similar load carrying capacity to a typical hot rolled structural section would not be as compact. Because of this and because of the additional residual stresses imparted into cold formed sections as a result of the cold forming process the inelastic ductility capacity of the sections is extremely limited. However all cold formed sections have some inelastic ductility capacity which depends to a considerable extent on the structural configuration in which the sections are used.

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2.2 Inelastic Behaviour

Reference (1) describes one of a series of portal frames tested under statically applied vertical loading. The test frame was constructed of two cold formed channel sections connected back to back by bolts at sufficiently frequent centres to form a single doubly symmetric section. The members were connected at the base, knees and apex by mild steel bracket assemblies designed to enforce failure in the cold formed sections.

Once local failure in the joints was suppressed by suitable detailing failure occurred in the cold formed members (usually in the columns). On average there was a 20 percent to 30 percent increase in deflection to failure as compared to deflection to first yield or local buckling. The load deflection curves showed little reduction in frame stiffness from yield to failure. Ref. (2) describes another set of loaded portal frame tests on frames consisting of single channel sections bolted together in a similar manner as were the frames in ref. (1). Furthermore in ref. (2) detailed analytical calculations were carried out to determine the theoretical frame failure loads. The results showed that the structures were able to support loads significantly higher than those which caused first yield, when the yield load was two to three times lower than the elastic local buckling load. The load deflection curves resembled those for portal frames constructed from hot rolled steel sections, with a region of sustained load carrying capacity under inelastic deflection. The reason for this was that a combination of major axis bending and warping torsion (bimoment) was the predominant design action on the single channel section. This resulted in progressive yielding across and along the channel flanges unlike the pure major axis bending predominant in the frames tested in ref. (1) which caused sudden yielding across the full width of the compression flanges with subsequent buckling failure.

Thus a doubly symmetric cold formed section exhibits less inelastic ductility capacity than a singly symmetric cold formed section. However both exhibit sufficient capacity to enable a seismic design to the elastic equivalent static force analysis procedure of NZS 4203 (5) to be undertaken on a structure in which the primary seismic resisting systems are composed of cold formed sections. Other design options are available where more (inelastic) ductility capacity is required.

3. SEISMIC DESIGN OPTIONS

There are three options available to designers wishing to use cold formed sections as the primary structural system when seismic loading is one of the critical design loads on the structure. These are now discussed in turn.

3.1 Elastic Design

The seismic loads on the structure are determined through the use of the equivalent static force analysis procedure (section 3.4) of ref. (5), for elastic structural response. The design of members is to an appropriate cold formed design code e.g. AS 1538 (6) or ref. (4).

Care should be exercised in choosing the correct structural type (S) factor. The percentage of critical viscous damping inherent in the structure is the major factor in determining elastic structural response for a given earthquake motion. Details on choosing the appropriate S factor for use with this elastic design method are given in ref. (7). For the fully bolted frames described in section 2.1 of this paper S = 4.9 should be used, based on a viscous damping percentage of 12.5 percent critical as obtained from ref. (7).

The design of members may be to either the alternative design provisions of NZS 4203 and the relevant cold formed member design code used or to the strength design provisions of NZS 4203 and the factored working stress design provisions of the member design code.

The factors to apply to the code member design procedures are 1.45 for shear and 1.67 for all other design actions.

No special detailing procedures are required.

3.2 Low Ductility Demand Design

Fig. 1 shows a typical knee joint detail for the portal frames tested in ref. (2). In this case the joint was designed overstrength to force failure into the cold formed section. However the opposite can be undertaken, with the joint constructed from hot rolled mild steel (grade 250) sections or built-up mild steel plate sections suitably designed and detailed to concentrate all the inelastic demand into the joint and produce the desired inelastic behaviour.

In this case the mild steel sections must be detailed to the low ductility demand requirements i.e. flanges must comply with clause 4.3.1 of ref. (8) and webs be fully effective in shear.

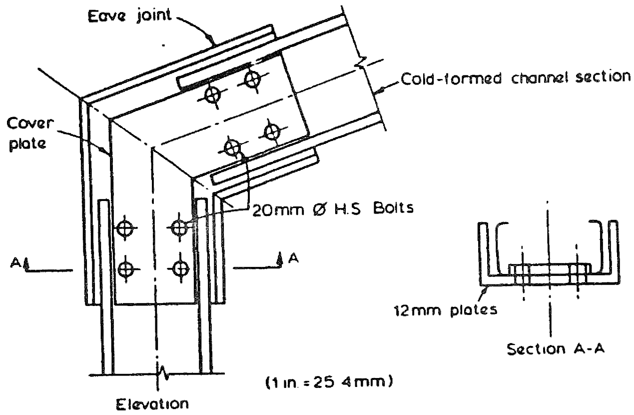

Fig. 1 Knee joint details

In this case the mild steel sections must be detailed to the low ductility demand requirements i.e. flanges must comply with clause 4.3.1 of ref. (8) and webs be fully effective in shear.

For low ductility demand design ($\mu = 2$) of these structures the appropriate S factor is determined from ref. (7). The design of the joint is to the strength design method of NZS 3404, using the strength design load combinations of NZS 4203. The cold formed sections are then designed for 1.35 times the capacity of the mild steel joint sections according to the factored working stress design methods given in either ref. (6) or ref. (4).

A tentative alternative low ductility demand design method is being formulated based on the inelastic capacity of compact cold formed sections as detailed in section 3.9 of ref. (4). The commentary to ref. (4) contains a list of background references to section 3.9 which are currently being obtained by the author. If these references show that suitably compact cold formed sections can exhibit a dependable ductility capacity of $\mu = 2$ over many load cycles then these sections will be able to form the primary seismic resisting system of the structure for low ductility demand design.

The author should be contacted for further developments.

3.3 High Ductility Demand Design

This also employs suitably positioned mild steel (grade 250) sections which are designed as the primary seismic resisting sections.

The level of seismic load is determined from ref. (5) for high ductility demand design. The design and detailing of the mild steel sections shall be to the provisions of section 10 of ref. (8) as modified by the requirements outlined in refs. (9,10). The cold formed sections shall be designed for 1.5 times the capacity of the mild steel sections according to the factored working stress provisions of refs. (6) or (4).

4. WELDING AND BOLTING REQUIREMENTS

The welding procedures and electrode types required for cold formed steel are determined by the composition of the steel and type, and position of weld required. Electrodes suitable for welding mild steel should be used.

There are no special seismic requirements necessary for welding or bolting cold formed sections. Extra care must be taken to ensure the minimum heat input required for laying down welds is used by specifying appropriate procedures and not over designing welds. The cold forming process puts very high residual stresses into a section and welding will tend to release these which can result in considerable deflections. Minimising the heat input will minimise these deflections.

5. PALLET RACKING SYSTEMS

These are skeleton frame structures designed to store produce usually stacked on pallets. The racks are designed for ready access by forklifts or other mechanical devices to facilitate rapid movement of stored material to and from the rack systems.

As such they are subject to a very specialised set of design requirements and constraints. Furthermore they are usually constructed of perforated cold formed sections and as such require consideration for seismic design.

Detailed description of the seismic design aspects of pallet racking systems is beyond the scope of this paper however information on the subject is available. The following references should be obtained by those wishing to design such systems:

(a) "Draft Seismic Design Standard for Industrial Storage Racks", proceedings of a seminar on pallet rack design held at HERA, Dec. 1983, available from HERA.

(b) Brown, B.J., "Seismic Design of Pallet Racking Systems", Bulletin of the NZNSEE, vol. 16, no. 4, 1983, pp. 291-305.

(c) Chen, C.K., Scholl, R.E. and Blume, J.A., "Seismic Study of Industrial Steel Storage Racks", URS/John A. Blume and Associates, San Francisco, June 1980.

(d) ANSI MH 16.1 - 1974: American National Standard for the Design, Testing and Utilisation of Industrial Steel Storage Racks.

6. CONCLUSION

This paper briefly covers the seismic design considerations required for structures utilising cold formed sections as the primary structural load carrying system and gives design options available to achieve the required level of seismic resistant construction.

7. REFERENCES

(1) Reay, A.M., "Report on the Testing of the Frame System for an 18 Metre Span Pool Cover", Consulting Engineer, Christchurch, Dec. 1981.

(2) Baigent, A.H. and Hancock, G.J., "The Strength of Portal Frames Composed of Cold-Formed Channels", Research Report No. R407, University of Sydney, March 1982.

(3) Reck, H.P., Pekoz, T. and Winter, G., "Inelastic Strength of Cold-Formed Steel Beams", Journal of the Structural Division, ASCE, Vol. 101, No. ST11, November 1975.

(4) "Specification for the Design of Cold-Formed Steel Structural Members", American Iron and Steel Institute, New York, September 1980.

(5) NZS 4203, 1984: "Code of Practice for General Structural Design and Design Loadings for Buildings", Standards Association of New Zealand, Wellington.

(6) AS 1538, 1974: "Rules for the Use of Cold-Formed Steel in Structures".

(7) Clifton, G.C., "The Estimation of Structural Type Factors for Use in NZS 4203:1984", New Zealand Heavy Engineering Research Association, March 1985.

(8) AS 1250, 1981: SAA Steel Structures Code, Standards Association of Australia.

(9) Walpole, W.R. and Butcher, G.W. "Beam Design", Section C - NZNSEE Study Group for the Seismic Design of Steel Structures, Bull. NZNSEE, Vol. 18, No. 4, December 1985, pp.337-343.

(10) Walpole, W.R., "Section H Beam Column Joints", NZNSEE Study Group on the Seismic Design of Steel Structures, Bull. NZNSEE, Vol. 18, No. 4, December 1985.