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# Pseudo-plastic moment resistance of continuous beams with cold-formed sigma sections at internal supports: An experimental study

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ABSTRACT

Most thin-walled sections exhibit elastic-softening moment–rotation characteristics in bending, and therefore the elastic analysis/design method is usually recommended for continuous beams with this type of section. A more economical design approach, the pseudo-plastic design method, has been proposed to allow for the development of moment redistribution in the system. To facilitate this design method, pseudo-plastic moment resistance (PPMR) at the internal supports is required. This paper reports an experimental study of the structural performance of continuous beams with cold-formed sigma sections near the internal supports, based on which the PPMR was derived. To this end, only the part of the beam carrying a hogging moment near one of the internal supports was specifically studied. It was represented with a simply supported beam subjected to a central point load. The simple supports were placed at inflexion points and the concentrated load was a representation of the reaction. Research results include the behaviours of initial buckling, post-buckling and post-failure of sigma beams near the internal supports, the ultimate moment resistance under combined bending and shear, and the moment–rotation relationship. Four typical localised collapse patterns have been established and defined. The results of ultimate moment resistance obtained were compared with the theoretical predictions by using two codified methods, namely, the effective width method (EWM) and the direct strength method (DSM). Lastly, a semi-empirical approach has been proposed to find the pseudo-plastic moment resistance at the internal supports.



## 1. Introduction

Cold-formed steel (CFS) sigma sections are commonly used as purlins and side rails in modern industrial buildings. Compared to their counterparts such as Z and C sections, sigma sections offer improved buckling resistance due to the presence of web stiffeners. As a result, the adoption of CFS sigma sections has been continually growing over recent years.

A typical moment–rotation relationship of a single-span CFS sigma beam can be schematically represented by the curve in Fig. 1. Three distinct stages can be identified from this curve: the linear elastic, the nonlinear stable post-buckling and the softening unstable post-failure stages. In the first stage, the cross-section is fully effective, and as such the beam exhibits a linear elastic behaviour. On the initiation of buckling, the cross-section gradually loses stiffness, and therefore the moment–rotation curve starts to become nonlinear. In this stage, the section can still carry increasing loads due to the post-buckling strength. As large buckling deflection develops, the material starts to yield, and once sufficient material yields within a cross-section, it ceases to carry any more loads and reaches the ultimate failure point. Beyond this point, the section develops a localised collapse mechanism and gradually loses moment resistance.

The design of CFS sections is usually based on elastic methods, e.g., the effective width method (EWM) [1] or the direct strength method (DSM) [2]. Both of these are well established for Z and C sections. Direct use of these methods for sigma sections, however, can introduce problems because of the presence of web stiffeners. Such problems can even be exacerbated if the section is under the concurrent action of bending and shear. Furthermore, using the elastic method to analyse and design multi-span beams will inherently result in uneconomical designs. Post-failure residual strength of the cross-section near the internal supports allows a plastic hinge zone to develop at a reduced level of moment resistance so that a pseudo-plastic collapse mechanism can be formed. This moment resistance is analogous to the full plastic moment resistance of compact sections and is referred to as the "pseudo-plastic moment resistance" (PPMR) hereafter in this paper. Under the chosen level of PPMR, adequate rotation capacity will be available near the internal supports for the system to develop moment redistribution and hence lead to a collapse mechanism. The immediate benefit of employing this

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