Structures 15 (2018) 13–27

Contents lists available at ScienceDirect

Structures

journal homepage: www.elsevier.com/locate/structures

Behaviour of Single Angle Connections Under Simultaneous Shear, Tension and Moment

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ARTICLE INFO

Keywords:
Finite element method
Progressive collapse
Column removal scenario
Shear connection
Single angle connection
Rotational ductility

ABSTRACT

There are several types of simple shear connection used in steel structures; single angle connections are one popular one-sided type for lightly loaded beams, as erecting the beam is facilitated. The current research aims to establish the characteristic robustness features of such connections in the column loss event. The actual load path, stress distributions, sources of ductility, and failure modes are studied to propose appropriate modelling parameters. Finite element analysis is utilized, and the models are verified with available experimental data. Models consist of a central short column connected to adjacent beams, simulating the removal of a column. The central column stub is pushed down, while the connection demand and performance are closely monitored. An extensive parametric study is performed to investigate the effects of different design parameters, such as angle geometry, bolt size and type, and connection depth. It is observed that the main source of ductility was unfolding deformation of the outstanding angle leg. The dominant failure mode was rupture of the angle at the bottom hole. The maximum rotation of single angle connections was between 0.23 and 0.16 rad for three to five bolt connections, respectively. The fasteners located at the bottom of the connection carry the largest load, which is accentuated as the rotation increases. The point that the flexural phase domination terminates and catenary force commences to provide the major resistance is named the “devolution point”. For three bolt connections, this point occurs where the flexural resistance is almost zero, whereas for five bolt connections, the devolution point occurs approximately at the peak moment. It is inferred that single angle connections fail mainly because of catenary action. An equation based on the connection depth is proposed to predict the rotational ductility of single angle connections when an adjacent column is removed. This study helps to quantify the behaviour of single angle connections in the column loss event, as well as providing a foundation to understand how they would perform under other extreme loading conditions.

1. Introduction

Single angle connections are one of the common single-sided shear connections used in steel construction. They are more economical than double angle connections due to reductions in both material and labour. They are also more favorable to fabricators due to ease of fabrication and beam installation. The angle can either be bolted or welded to the beam web and bolted or welded to the column flange, as shown in Fig. 1. The leg that is bolted or welded to the supporting member is called the “outstanding leg”; meanwhile, the other leg that is connected to the supported beam is called the “web-framing” leg [1]. Common types of material used in single angle connections are stated in Table 1. Similar to other types of shear connections, single angles in beam-to-column connections are conventionally designed to transfer shear forces, while the rotation is not restrained. As a result, there is no substantial moment or axial force transfer. However, current progressive collapse design guidelines, such as DoD [2] and GSA [3], ask designers to specify robust connections that maintain their integrity in a double-span column loss event in which the connection sustains significant amounts of tension and moment. Additionally, these guidelines provide tables that include models for rotational ductility of shear tab and double angle connections, but not single angles. Consequently, there is a necessity to investigate anticipated shear connection performance under a column removal scenario. The behaviour of single angle connections under a column removal scenario is perhaps the least researched of all common connection types, yet an essential aspect of assessing the general performance of steel structures against extreme loading.

The focus of the research is on bolted-bolted single angle shear connections, shown in Fig. 1(d). Numerical studies of single angle

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https://doi.org/10.1016/j.istruc.2018.05.005
Received 26 January 2018; Received in revised form 5 May 2018; Accepted 9 May 2018

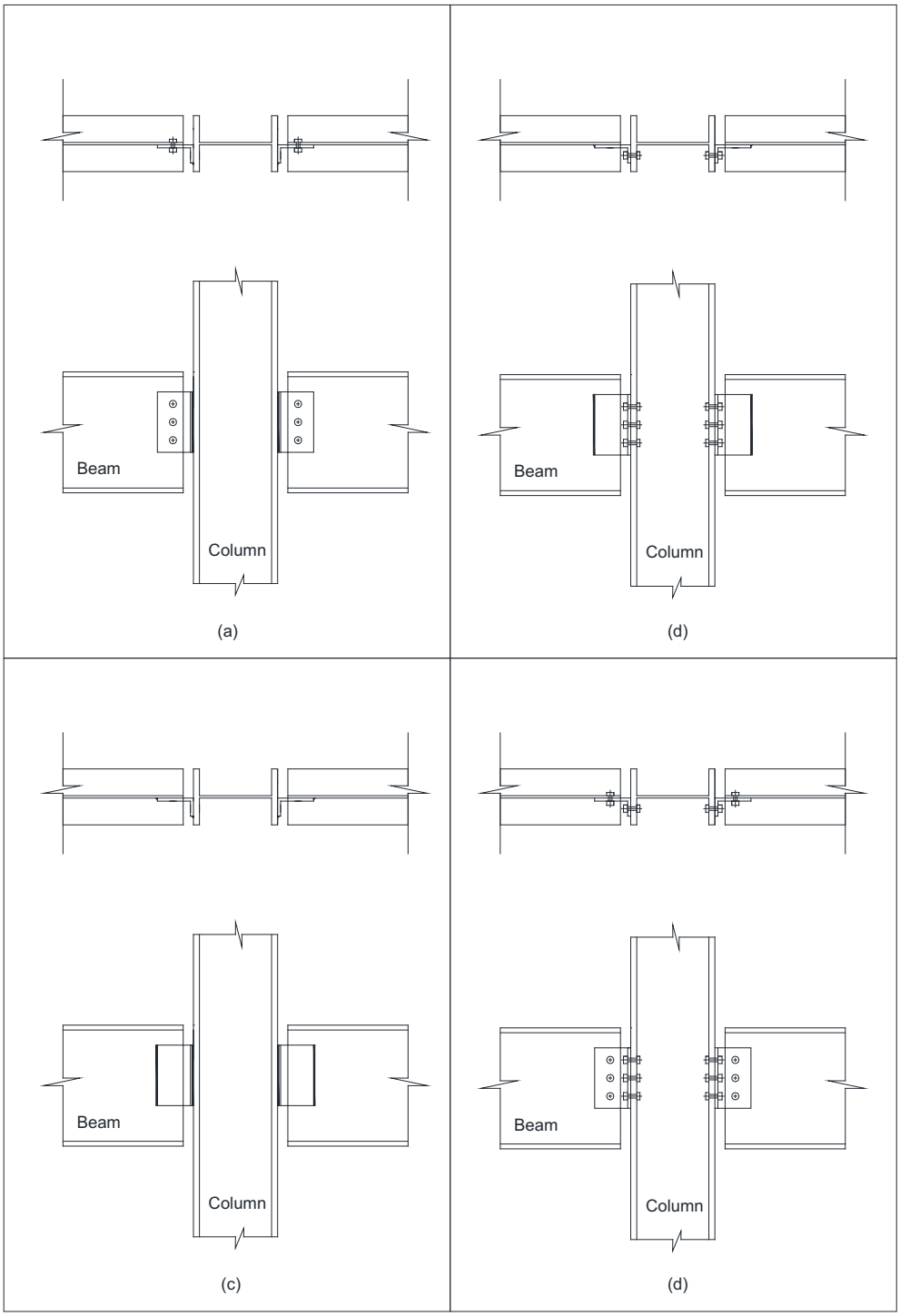

Fig. 1. Types of single angle shear connections: (a) welded-bolted (b) bolted-welded (c) welded-welded (d) bolted-bolted.

Table 1
Typical material used for single angle connections.

Component	Material	Description
Angle	ASTM A36; CSA 300W, 350W	–
Bolts	ASTM A325, A490	Standard/slotted hole
Welds	E70XX electrode	Fillet welds

connections under column loss demands are performed and the results are verified with available experimental data. The verified models are then used to shed more light on the connection's performance and sources of ductility by expanding the available database. Shear, tension, and moment versus chord rotation diagrams are created based on the simulation results and conclusions are drawn. The results are used to select suitable connection modelling parameters for progressive collapse evaluations of steel frames with similar single angle shear connections. Connection depth, angle thickness, bolt size and type are the main variables in the numerical models discussed herein. Equations,