Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
International Journal of Impact Engineering 31 (2005) 861–876
INTERNATIONAL JOURNAL OF IMPACT ENGINEERING
www.elsevier.com/locate/ijimpeng

Finite element analysis of steel beam to column connections subjected to blast loads

Tapan Sabuwala, Daniel Linzell*, Theodor Krauthammer

Department of Civil and Environmental Engineering, The Pennsylvania State University, State College, PA 16802, USA

Received 28 August 2003; received in revised form 20 April 2004; accepted 23 April 2004

Available online 26 June 2004

Abstract

The behavior of fully restrained steel connections subjected to blast loads was examined using finite element analysis. Two connections that were tested as part of the AISC Northridge Moment Connection Test Program (Report for AISC, 1994) were studied using ABAQUS. Models were validated by comparing numerical results against AISC Program experimental data. Validated models were then subjected to simulated blast loads and their efficiency against those blast loads was verified based on criteria specified in TM5-1300 (Department of the Army, Structures to resist the effects of accidental explosions, 1990). Adequacy of TM5-1300 criteria was investigated and critical zones in the connection details were identified. Based on the results of the study, recommendations for modifications to TM5-1300 criteria were made and the effectiveness of the chosen connection details under blast loads was summarized. The results showed that the TM5-1300 criteria for steel connections subjected to blast loads are inadequate. Also the unreinforced (pre-Northridge) connection detail performed poorly under blast loads with excessive deflections and above yield stresses in the connection region while the reinforced connection detail showed improved resistance against blast loads and this connection may be an option when detailing steel framed connections to resist blast loads.

Keywords: Blast loads; Finite element modeling; Steel connections

1. Introduction

The study of steel connections subjected to dynamic loads was initiated in the 1960s by Popov [1] wherein tests were conducted to study the cyclic behavior of steel moment-resisting

*Corresponding author. Fax: +1-814-863-7304.
E-mail address: dlinzell@engr.psu.edu (D. Linzell).

doi:10.1016/j.ijimpeng.2004.04.013

connections. Since these early studies, investigations have generally focused on their behavior under cyclic loads, such as those generated during an earthquake. However, since September 11th, there is rising concern in the United States over the safety of building structures subjected to blast loads. When a structural steel frame is subjected to blast loads, the beam-to-column connections, which are responsible for load transfer between different members within the frame, play a major role in structural response. Thus, a better understanding of the behavior of structural steel connections under blast loads is of prime importance. However, few studies have been conducted which analyze the interaction of blast loads and structural components of building structures. Case studies based on past attack on buildings subjected to blast loads have been presented such as by Caldwell [2] which focus on the pattern and severity of blast damage sustained by the structure. Most of these studies however take a macro view of the situation and analyze the effect of blast loads on the buildings as a whole instead of identifying the behavior individual structural components of the building structure under such loads. No experimental studies have been reported that analyze the behavior of steel connections under blast loads. Only one theoretical study [3] and one numerical study [4] investigating steel connection behavior under blast loads has been reported.

While some general publications, as that published by Conrath et al. [5], dealing with the design of structural systems to resist blast loadings exist, there are only a limited number of code documents that exist related to blast design. The principal code currently used for the design of structures in the United States to resist blast loads is TM5-1300, *Structures to resist the effects of accidental explosions* [6]. This document provides guidelines for the safe design of structural elements subjected to short duration dynamic loads (i.e. blast loads) and criteria contained within TM5-1300 are oriented toward industrial building applications common to ammunition manufacturing and storage facilities, (i.e., relatively low, single-story, multi-bay structures). The approach presented in TM5-1300 is centered on the response of structures and structural elements that are idealized as equivalent lumped-mass single degree of freedom systems. While general criteria for proportioning low-rise framed military structures to resist blast loads are provided, this publication does not provide specific design guidelines or performance criteria for steel connections under blast loads. Hence the performance of a steel connection has to be judged based on the performance of the steel frame. However, the adequacy and effectiveness of criteria given in TM5-1300 for steel frames is not well understood due to limited research. Hence, given the absence of specific criteria governing connection behavior under blast loads, this study aimed at verifying the adequacy of criteria presented in TM5-1300 for steel frames containing select connection details. Moreover due to the lack of research and specific design guidelines for blast-loaded steel connections, existing connection details proven to be effective against dynamic loads were selected in order to obtain an initial understanding of their effectiveness and behavior under blast loads which can then be used as a stepping stone for future studies in this area.

2. Experimental program

Connections selected for the current study were tested as part of the AISC Northridge Moment Connection Test Program. The study was conducted by Engelhardt et al. [7] immediately after the Northridge earthquake to provide insight into causes of steel connection failures and to provide