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Evaluation of progressive collapse alternate load path analyses in designing for blast resistance of steel columns

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ABSTRACT

The alternate load path method is a convenient, "threat-independent" method used in progressive collapse analysis and design. Because no actual loadings are considered in this method, the resistance provided by the alternate load path method for specific extreme events is not well quantified. However, such quantification allows for an understanding of what real scenarios can be efficiently represented by alternate load path analyses. As blast loading is one of the abnormal loading events typically motivating an alternate path analysis, this load type is selected for evaluation in the present work. In order to find the blast threat that is representative of the alternate load path method in steel-framed buildings, finite element analyses of steel columns being subjected to blast loads were analyzed in the program LS-Dyna. Prior to this, sensitivity and validation studies were also completed, which are described herein. The results of the column analyses show that failure is governed by a stability-based deflection criterion. Conclusions regarding the charge sizes that the alternate load path method may be considered to be representative of, as well as the influence of column spacing, size, and end fixity on these results are given.

1. Introduction

The alternate load path analysis method is quite popular because it is easily incorporated into design codes, engineers are familiar with the analysis methods accompanying it, and consideration of the initial loading event is not needed. These features currently make it one of the most efficient options available for performing a progressive collapse analysis and assessing the redundancy of a structure. However, it is not the intent of this method to give a direct indication of the structure's ability to withstand a true abnormal loading.

The primary motivation of this work was to shed light on what real scenarios correspond to the state of damage implicitly assumed in the alternate load path analysis method — failure of one and only one column. Realizing that it is not the intent of this methodology to represent any specific loading, this information is nonetheless useful for two key reasons. First, this information can inform the profession's understanding of the connection between real threats and the assumed state of damage inherent to alternate load path analysis. Second, once realistic scenarios that can be enveloped by the alternate load path analysis method are known, labor-intensive threat dependent analyses for these threats can be minimized if desired. Thus, the goal of this work was to determine a practical range of blast threats that can be accurately and efficiently represented by an alternate load path analysis. In practical terms, this means it is to be established what blast threats will cause the failure of no more than one column. The research also takes column size, spacing, fixity, and service loading into consideration and final conclusions are formed in terms of column spacing and end restraints. The research is limited to considering columns only, however; no other structural or non-structural components are considered in the present study.

The literature on progressive collapse is vast, ranging from initial work on the topic in the 1970's through work spurred by a resurgence in interest in this topic as a result of terrorist activity in the early part of the present century. Of this large body of research, the works most relevant to the present study are research addressing the performance of steel-framed buildings during blast scenarios. Marchand and Alfawakhiri [1] have reviewed the best-practices with respect to both progressive collapse and blasts for steel-framed buildings. Hamburger and Whittaker [2] also review the current practice relating to blast-related progressive collapse for steel-framed buildings, while Krauthammer [3] reviews the background on blast effects and focuses on connection performance in steel-framed buildings. All of these documents emphasize the need for ongoing research. In particular, Marchand and Alfawakhiri state that an understanding of the effectiveness of progressive collapse design methodologies in resisting "real" threats is a key issue to be addressed. This work directly relates to this need.

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