Disproportionate Collapse Design Guidance in the United States

By David Stevens, Ph.D., P.E., M. ASCE and Mark Waggoner, P.E., M. ASCE

Disproportionate collapse of structures continues to be an exciting topic in structural engineering, given its public safety implications, philosophical aspects, technical challenges, and opportunities for designers to expand their technical skills while proposing unique solutions. Research is actively underway in the US and many other countries, in both university and government laboratories, and technical sessions on disproportionate collapse at recent Structures Congresses have been lively and well-attended.

In addition to research developments, the state of disproportionate collapse design guidance continues to advance in the United States, with three recent and significant events: (1) initiation of a performance-based design standard for disproportionate collapse by SEI; (2) development of new General Services Administration (GSA) design guidelines, soon to be released; and (3) the recent release of Change 2 to the Department of Defense (DoD) design guidelines.

SEI recently formed the Disproportionate Collapse Standards Committee (DCSC), whose goal is to develop a consensus-based approach for designing structures to resist disproportionate collapse. The first full committee meeting was held at the Pittsburgh Structures Congress in May 2013, with many of the 50 or so members in attendance. Subcommittees for each of the nine planned chapters have been formed, and corresponding white papers have been developed. The DCSC hopes to finish the standard within five years.

The development of this SEI standard is noteworthy for a number of reasons. This will be the first consensus-based standard developed in the United States for disproportionate collapse; many other countries already have such design guidance. Perhaps more significantly, this standard will be performance-based; a lively discussion of the merits of prescriptive- and performance-based design occurred at the Pittsburgh meeting, and the committee decided to pursue a performance-based approach, in line with developments in design procedures for other extreme events (e.g., seismic).

The development of the standard will be challenging, given that this will be the first performance-based disproportionate collapse design approach anywhere in the world, and thus will require careful deliberation. The proposed performance-based design method intends to incorporate proportionality through the use of a suite of hazards of varying size and corresponding categories of performance. Research is currently underway on the appropriate levels of performance that can be readily supported by available methods of design.

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GSA has recently undertaken the development of a new set of guidelines for progressive collapse design, tentatively titled *Alternate Path Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects*. When issued, this document will replace the 2003 GSA guidelines. The goals are to bring alignment with the security standards issued by the ISC and GSA, and to reduce inconsistencies between GSA and DoD design approaches. The focus of the guidelines is mitigating progressive collapse due to man-made explosive threats at the ground level and in high-risk public areas. These guidelines are threat-dependent and incorporate a risk-based approach, such that application is dependent on the required level of protection as determined by the Facility Security Level (FSL) or facility-specific risk assessment. Reduction of progressive collapse potential can be achieved either by precluding failure of load-carrying elements for a defined threat or by bridging over their loss.

The Alternate Path (AP) method, in conjunction with new redundancy requirements, is used exclusively for verifying that the structure can bridge over a lost load-carrying element; tie forces and specific local resistance are not employed. In the new GSA guidelines, the AP method is based on the methodology and performance requirements presented in the DoD Unified Facilities Criteria (UFC) 4-023-03, *Design of Buildings to Resist Progressive Collapse, and ASCE 41, Seismic Rehabilitation of Existing Buildings*, with some modifications and additions. The intent of the redundancy requirements is to distribute progressive collapse resistance up the height of the building without explicitly requiring column/wall removal scenarios at each level. One significant difference from UFC 4-023-03 is that the acceptance criteria for existing buildings will allow a specified amount of local damage in the vicinity of the column or wall removal location, providing that the designer can show that the damaged or failed portion does not create deleterious loading on the floors below.

After four years of application of the 2009 version of UFC 4-023-03, DoD released Change 2 in June 2013. There are a number of significant modifications and improvements, including revised peripheral tie force equations that now directly include façade loads, resulting in smaller peripheral tie forces for framed structures. For one-way load-bearing walls, both the wall loading and façade loading are included in the peripheral tie force requirements. The applied load combinations were revised to remove the 0.9 factor on the dead load, as well as the lateral load requirement. The example problems in the appendices now include a cold-formed steel project. The enhanced local resistance approach was recast in an LRFD format. Finally, the cost of implementing progressive collapse design requirements was investigated as part of the effort to revise the 2009 UFC 4-023-03, using cost estimates for the four example problems.

In summary, significant advances have been made and are underway in the design of structures to resist disproportionate collapse. The next major development will be the release of the GSA design guidelines in 2013, followed by the release of the ASCE SEI disproportionate collapse design guidelines, hopefully within the next five years.▪

*David Stevens, Ph.D., P.E., M. ASCE (**dstevens@protection-consultants.com**), is a Senior Principal at Protection Engineering Consultants in San Antonio, Texas.*

*Mark Waggoner, P.E., M. ASCE (**mwaggoner@walterpmoore.com**), is a Principal at Walter P Moore in Austin, Texas.*