Bracing for Blast

BY PATRICK NEWMAN, P.E.

AISC's new Design Guide 26 provides engineers with information on designing structures for blast resistance and progressive collapse.

DESIGNING A BUILDING for blast resistance or progressive collapse? AISC's new design guide can help.

Design Guide 26 *Design of Blast Resistant Structures* provides blast-resistance and progressive collapse design information to the structural engineering community, presenting basic theory with examples that can help guide engineers achieve simple and effective designs based on the blast pressures given by a blast consultant. A collaborative effort by several blast and collapse experts, the document was created in response to an increased need for guidance for blast resistance for buildings that house—or are in close proximity to those that house—explosive materials, as well as buildings that are seen as potential targets for attack. However, the need for blast and collapse design has increased in response to heightened risk to these facilities; a history of the blast incidents that have driven this heightened risk is included. (The lead author is Ramon Gilsanz, S.E., P.E., a partner at Gilsanz Murray Steficek LLC. Additional authors include Ronald Hamburger, S.E., P.E., senior principal at Simpson Gumpertz and Heger; Joseph L. Smith, director and senior vice president of Applied Research Associates, Inc.; Darrell Barker, P.E., vice president for Extreme Loads and Structural Risk at ABS Consulting; and Ahmad Rahimian, S.E., P.E., Ph.D., chief executive of WSP in New York.)

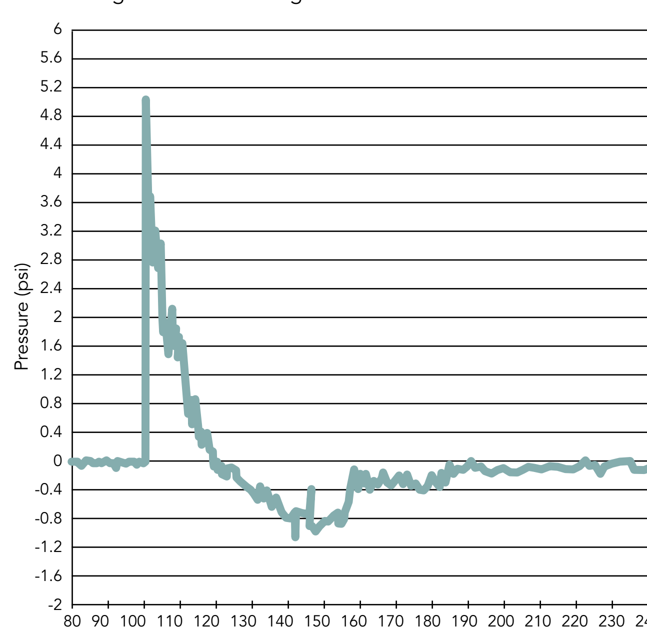
Blast Loads

Let's take a look at some of the guide's key aspects, starting with loading. Blast loading is different from the typical loading that is used in most structural designs. It results from an explosion created by a rapid expansion that creates a pressure disturbance or blast wave that radiates away from the explosion. Blast loads have a large magnitude and a short duration. The speed with which the blast load is applied significantly exceeds the loading rate of an earthquake.

In addition, blast loads can change significantly over the height of the building because of the variation in distance from the blast. The path that the blast load follows through the structure is similar to that for wind loads. All of these factors are taken into account in the design guide when determining the loading for a design. Simplified approaches are also covered and are easy to use for preliminary evaluation or design. In these simplified approaches the surface is divided into a grid and the pressure and impulse are investigated at the center of the grid point. Greater accuracy can then be achieved by creating a higher resolution grid. See Figure 1-1 from the guide, which illustrates a load history for blast.

Patrick Newman is a senior engineer–continuing education in AISC's engineering and research department. You can reach him at **newman@aisc.org**.

Figure 1-1 from Design Guide 26.



Blast Design

Following blast loads, the design guide includes information on the response of the structure. The methods of dynamic analysis for blast design are discussed as are the method for simplifying a multiple-degrees-of-freedom (MDOF) system into a single-degree-of-freedom system (SDOF) and the approach for determining the dynamic response.

Figure 6-11 from the guide illustrates the process that was followed. Within this equivalent SDOF system, the necessary yield force is found from the total energy and maximum deflection in the system. This yield force is then converted back to the MDOF system and the maximum moment is found, and a section is designed with this moment to determine the required plastic modulus conventionally.

From here, the guide delves into the design of the lateral load resisting system; blast loads rarely affect the lateral load resisting system but frequently affect the design of individual loaded elements and their connections. Again, simple procedures are shown and applied to the design of the lateral system. Design examples are also included, with step-by-step procedures.

Member and connection design is also included as are explanations for various failure modes, including breaching, tension-compression, bending, shear and axial-bending interaction. Strength increase factors and dynamic increase factors are also described and illustrated.

Design examples, which follow the load path from the façade to the lateral load resisting system, are provided as well. Member examples include façade girt, façade column, perimeter beam and elements of the lateral load resisting system.

Connection design, an important consideration in all building design—and especially so for blast design, as the connections are expected to perform into the inelastic range—is also covered. The guide stipulates an increase in the specified minimum yield stress and ultimate tensile strengths to account for and to be consistent with the dynamic increase factor applied to the member designs.

In addition, the guide lists some of the more popular structural analysis programs found in design offices and their ability to perform the various types of analyses shown in the design guide in regard to blast response evaluation.

Progressive Collapse

The new guide also covers the requirements for designing to prevent progressive collapse. Progressive collapse is defined by ASCE as "the spread of an initial local failure from element to element, resulting eventually in the collapse of an entire structure or a disproportionately large part of it." It is independent of blast design and may be caused by something other than an explosion; fires, accidents and impacts are all examples of events that may cause progressive collapse.

Figure 6-11 SDOF Solution from Design Guide 26.

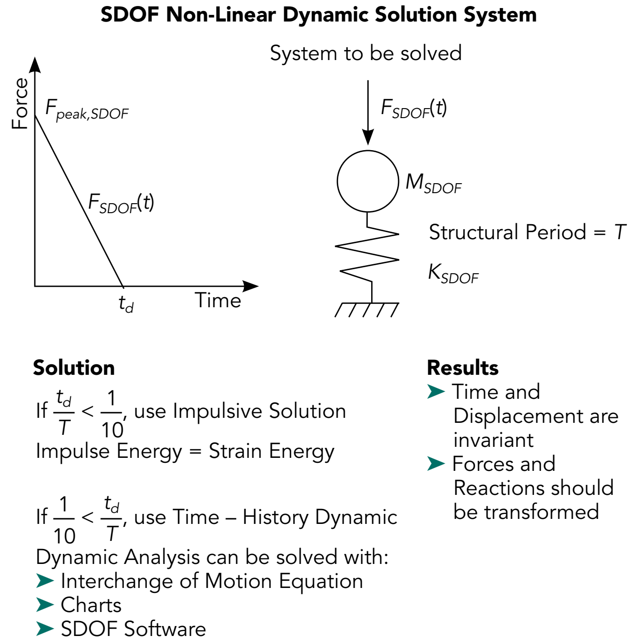
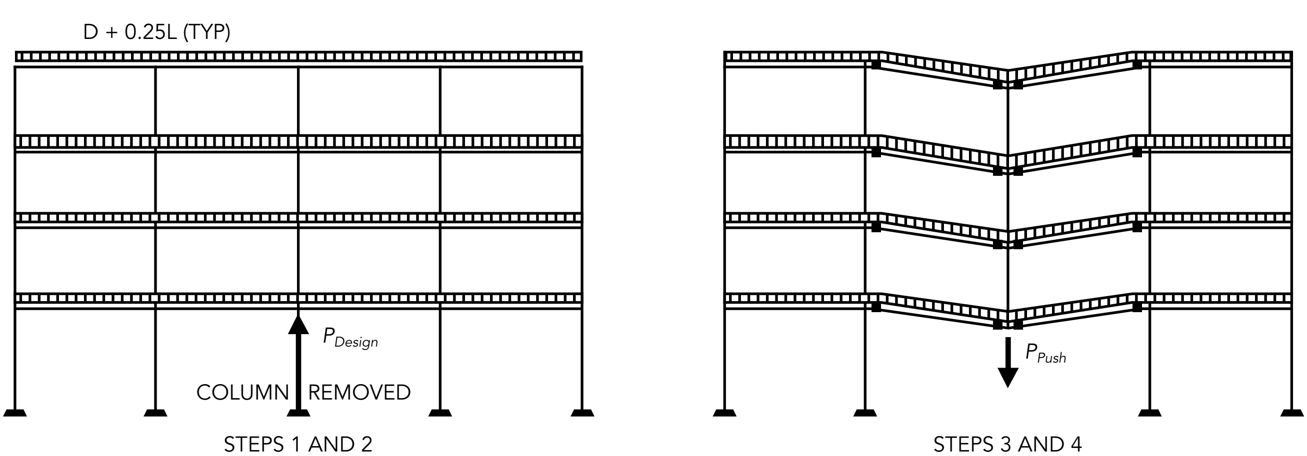


Figure 8-5 from Design Guide 26.



This design guide reviews the current state of the art for progressive collapse design in the U.S. and the UK. Specifically, it looks at the proposals from the U.S. General Services Administration, U.S. Department of Defense and British Standards—guidelines that will help in determining when and how one can do a progressive collapse design in those countries.

Progressive collapse is driven in large part by the self-weight of the structure. Since steel structures are relatively lightweight, they are well suited for structures where progressive collapse is a concern. Using the recommendations in this design guide an engineer can design redundant systems, and current recommendations from around the world are reviewed.

Progressive collapse design can be challenging; it is difficult to identify the load case to be examined. It is also highly nonlinear in both material response and geometric formulation; dynamic effects play a large role in progressive collapse response. Figure 8-5 from the guide shows an example of the frame energy balance procedure that can be used for progressive collapse resistant design.

Growing Guidance

When blast effects are a design consideration, blast mitigation design should be integrated with the overall structural design and not left until some later design stage. Blast mitigation design may increase the stiffness or the mass of the structure, which can affect the response of the structure to other loads. Design Guide 26 demonstrates ways to evaluate and design your structures for considerations of blast, and provides plenty of information to allow practicing structural engineers with a background in structural dynamics to interact with blast consultants to produce effective designs.

AISC continues to grow the Design Guide series, a collection of documents that cover specific topics in depth and serve as valuable assets to the steel design community. As with all of the Steel Design Guides, Design Guide 26, *Design of Blast Resistant Structures* is available as a free download for all AISC members; hard copies can also be purchased for your library. Visit **www.aisc.org/store**. MSC