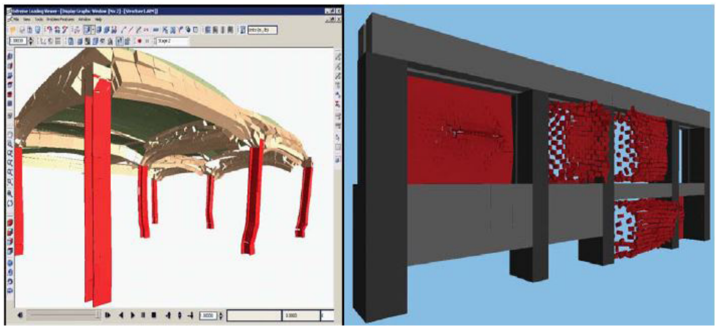
APPLIED SCIENCE INTERNATIONAL SUCCESS STORY

PROGRESSIVE COLLAPSE ANALYSIS IS A MUST:

ASI's Extreme Loading® for Structures Software is the Perfect Tool

There is an international trend for updating structural design requirements to explicitly design structures to resist progressive collapse. Among the codes that were recently updated to include specific clauses to require structural integrity of the structure to rule out the possibility of progressive collapse are the following codes:

American Society of Civil Engineers (ASCE/SEI 7-05), American Concrete Institute (ACI 318-05), National Building Code of Canada (NBC 2005), International Building Code (IBC 2009), Eurocode 1, British Standard Institute (BS 5950-2000), and Saudi Building Code (SBC 301-2007).



Analysis of reinforced concrete, steel, and masonry structures subjected to blast loading

Additionally many governmental bodies have released specific codes for design of special structures to resist progressive collapse, for example, US General Services Administration, US Department of Defense, and US Federal Highway Administration.

Almost all commercially available software is based on the finite element method (FEM) and is not suitable for progressive collapse analysis. FEM programs can be categorized into two groups: simplified ones and advanced ones. Simplified FEM analysis is relatively quick and easy to use; however, it does not consider any of the important factors required for an accurate progressive collapse analysis. Hence, using simplified FEM tools will result in highly approximated results and the engineer is obliged to increase the factor of safety resulting in a corresponding increase of construction cost. On the other hand, advanced FEM tools are complicated, time consuming and need very qualified users. Additionally, it is not practically possible even with advanced FEM software to automate the process of monitoring discrete crack propagation for the whole structure.

ASI Competitive Edge

The ASI competitive edge in progressive collapse analysis is largely based on its patented methodology implemented in its in-house developed Extreme Loading® for Structures (ELS) software. ASI experts use the Applied Element Method implemented in ELS to track the structure during the elastic behavior stage, cracking, larger deformation, element separation, rigid body motion of debris, collision between falling debris and other structural components. In ELS, the mode of failure or

collapse is a direct output of the analysis: the user will automatically be able to see the extent of the expected collapse due to any applied case of loading. The visual output helps the designer determine the shape and dimensions of

the expected collapse area. ELS enables ASI engineers to reliably perform complicated structural analysis in a fraction of the time required to do the same analysis by any other analysis tool. Thus, ASI has a unique ability to provide economical, practical, and reliable progressive collapse and blast analysis.

Progressive Collapse of Steel structures ASI competitive edge The ASI competitive edge in progressive collapse analysis is largely based on its patented methodology implemented in its in-house developed ELS software. ASI experts use the

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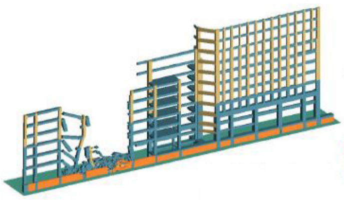
ELS Empowers ASI Engineers to

- Check the structure based on the requirements of relevant progressive collapse codes such as GSA or UFC guidelines
- Estimate pressure distribution on a specific structure based on a multiple threat scenarios
- Analyze structural and non-structural components such as windows, doors, infill walls, pipes, tanks, and equipment
- Determine the shape and dimensions of the expected collapse area
- Re-design the building to resist blast and/or progressive collapse
- Test strengthening schemes of the weak points in the building
- Determine speed of debris or glass fragments

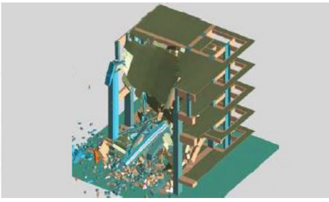
Progressive Collapse of Steel Structures

ASI Progressive Collapse Analysis Projects

The advantage of the progressive analysis performed by ELS has been demonstrated in many projects:



Partial Collapse Scenario due to column removal

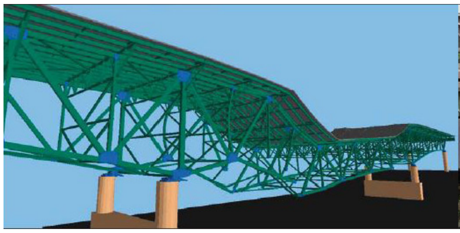


Progressive Collapse of part of the structure

name of the tower is withheld for security reasons) The tower is 56 stories, 800 feet tall, and has a price tag of about $880 million. Applied Science International (ASI) was tasked with assessing the structure's vulnerability in several scenarios with different positions for the blast inside and outside the building with different weights for the explosive charge, taking into consideration vertical loads inherent in the structure. Some of the results are highlighted:

One of the recent tragic examples of progressive collapse is the case of I-35W steel deck truss bridge located in the city of Minneapolis in United States. The bridge collapsed entirely on the first of August 2007 resulting in about 115 casualties. ASI was involved in a forensic analysis to identify the reason of the catastrophic failure of the bridge. A sophisticated model was done by modeling the connections in detail (gusset plate and bolts) and the weakening in the connection, caused by the corrosion, was modeled by using a gusset plate with reduced thickness. The results of these analyses helped identify the cause of failure of the bridge. The resulting mode of failure was very close to the mode of failure observed in the actual failure.

Many other steel deck truss bridges which have determinate systems - with little or no redundancy - can progressively collapse over the entire span if a single primary member or gusset plate connection of the main trusses fails. The analysis done by ASI can be repeated for those bridges to identify weak points and strengthen the bridges accordingly.



Snapshot of the ELS model halfway through failure

Actual failure of the bridge

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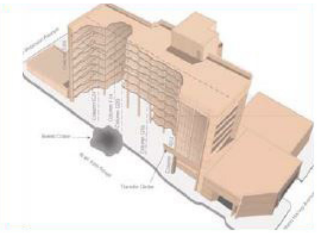
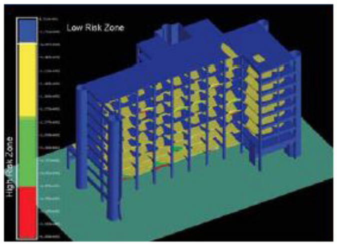
Investigation of the Oklahoma 1995 Bombing

The Murrah Building was the target of a terrorist attack in which a truck bomb was detonated in front of its north side destroying almost all the north half. ASI performed three-dimensional structural analysis which showed that the column nearest to the bomb location was destroyed as a direct result of the blast, which resulted in the failure of the transfer girder above it. This led to progressive collapse of the girders on the fourth through ninth floors. The results of the analysis agree with the observed failure mode.

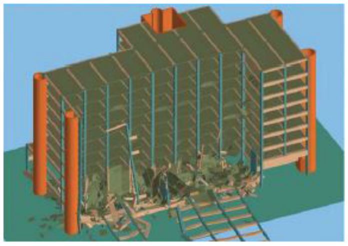
Actual failure



Sketch of failure (ASCE Report)



Post Failure Risk Zone Classification



Failure predicted by ASI

List of other recent ASI progressive collapse analysis projects

- Defense Threat Reduction Agency Project, HDTRA1-09-P0006 “High Fidelity Modeling of Building Collapse with Realistic Visualization of Resulting Damage and Debris”, Phase I, 2009.
- Collapse Analysis of Brown Brewery, Newcastle, UK, June 2008.
- Collapse Analysis of St Francis Hospital, Pittsburgh, USA, February 2008.
- Collapse Analysis of Stubbs Tower, Georgia, USA, December 2007.
- Collapse analysis of Charlotte Coliseum, North Carolina, June 2007.

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