APPLIED SCIENCE INTERNATIONAL

Performance Lifecycle Solutions

Resilient Design & Rehabilitation

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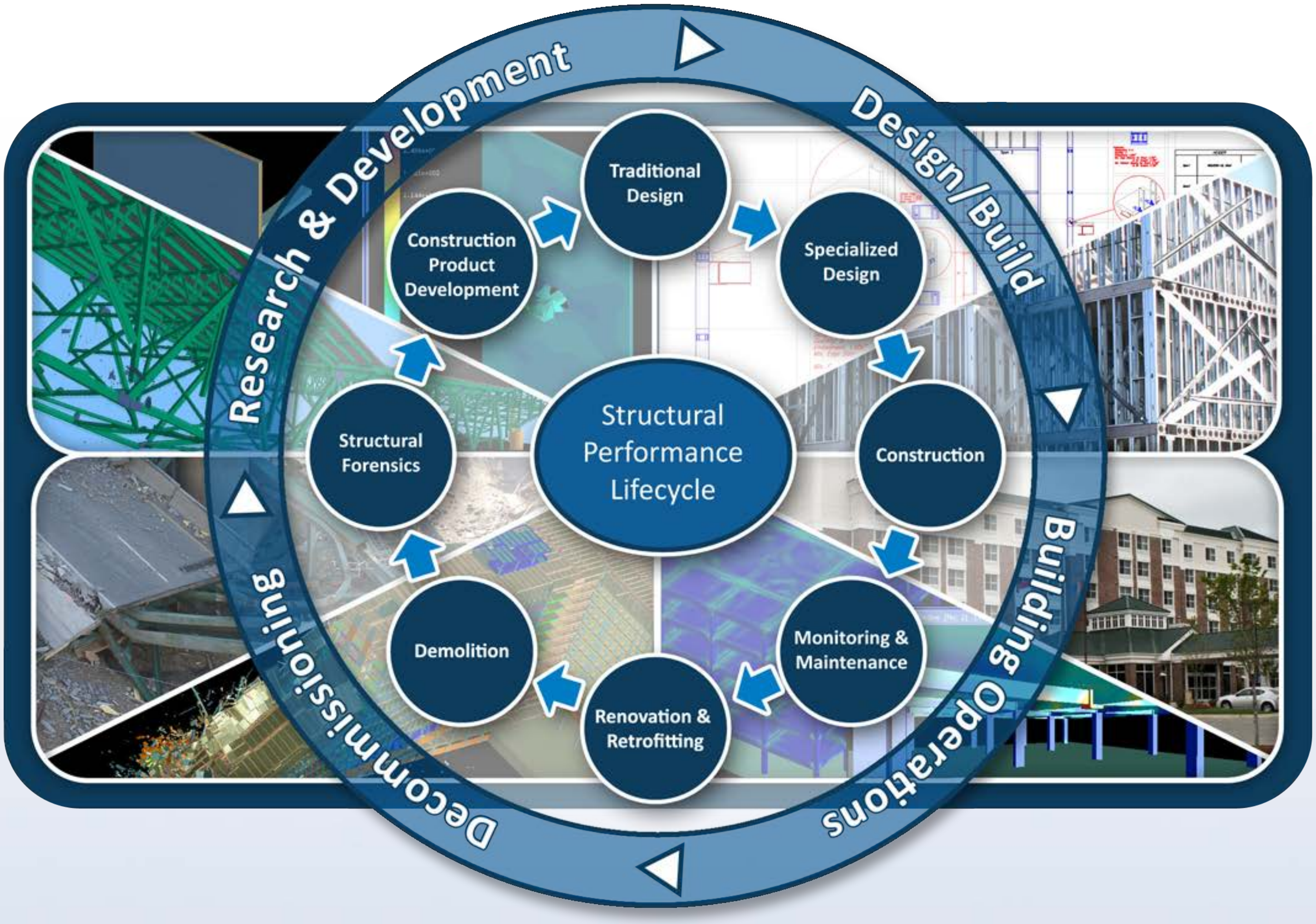
Structural Performance Lifecycle - Resilient Design

Make better decisions throughout the structural lifecycle by more accurately analyzing and visualizing structural health for resilience and the cost/benefit of robustness.



Uncompromising Resilient Design:

At ASI, our focus is on the development of practical solutions through simplifying the process, not the analysis method. These solutions help the practicing engineer to design greener, more efficient structures which can not only provide significant cost savings, but design structures that better ensure the safety of its occupants.

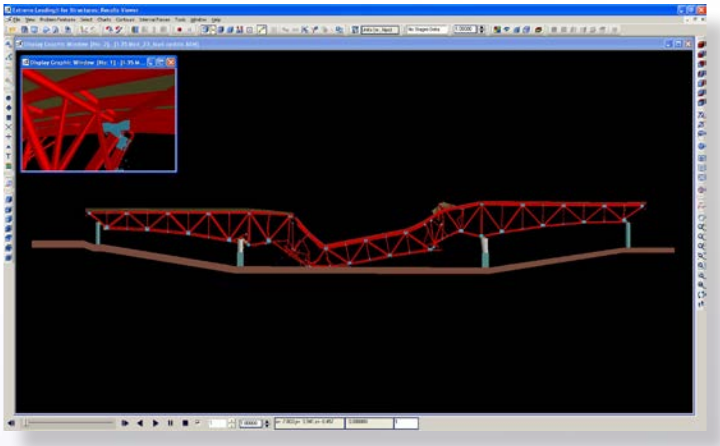
When studying a problem, Engineers look for ways to practically and effectively solve a problem in a way that make the study practical to the time allotted, budget, and technology available. The result has been the use of conservative code requirements paired with analysis solutions that sacrifice accuracy through simplified input and analysis.

The performance lifecycle of structures is a frequently discussed issue within the engineering community due to a range of challenges which include: aging infrastructure, recurring man-made and natural disasters, new construction materials, environmental sustainability, and the introduction of BIM.

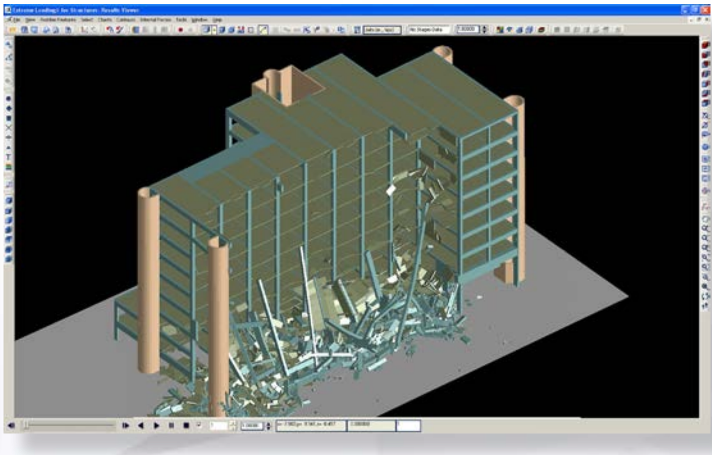
With the integration of BIM into the design of structures, the performance based life-cycle analysis is becoming an integrated process. This process looks at all phases of a structural system from design, to maintenance, extreme events, rehabilitation, and eventual demolition or forensics. With recent advances in structural analysis technology, simplified analysis is not the only economical solution. In fact, in many cases it is costly when compared to a performance based analysis of the entire structure. These solutions can result in the reduction of structural cost, decrease the construction timetable and increase security of the structure against performance requirements.

Rapid Performance Based Structural Analysis

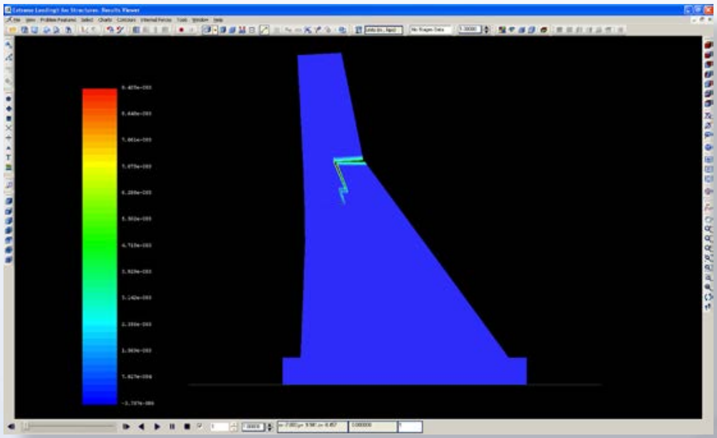
Practical engineering research, analysis, & design based on the performance of the entire structural system.



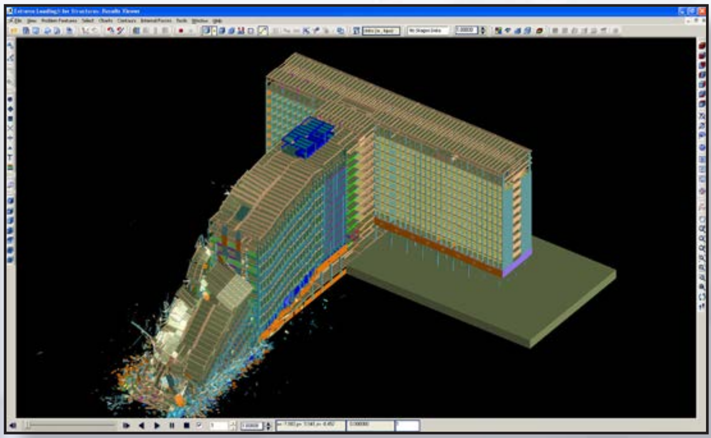
Minnesota I-35W Bridge



Alfred P. Murrah Federal Building



Koyna Dam



Rio de Janeiro University Hospital

ASI Services:

- Blast, Impact, Progressive Collapse, Seismic, & Wind Analysis
- Cold-Formed Steel Design
- Custom Software Development
- Demolition Analysis & Planning
- Forensic Engineering, Accident Reconstruction & Expert Witness
- Historic Preservation
- Renovation, Rehabilitation, & Retrofitting
- Performance Based Design
- Structural Building Information Modeling (BIM)
- Structural Vulnerability Assessment

Since 2004, Applied Science International (ASI) has focused on creating tools for professionals and researchers to help optimize and analyze structures. ASI has two core areas of focus: the study of structures under extreme loads with our advanced Extreme Loading® Technology and cold-formed steel design with our unique SteelSmart® Technology. Our team consists of highly talented engineers and scientists located at our corporate office in Durham, NC, and our division office in Cairo, Egypt. ASI's mission is to provide professionals with advanced software tools, support, and analysis.

When it comes to specialized design, extreme loading conditions, or structural failures, ASI's team of veteran engineers and scientists provides a collective wealth of hands-on experience in engineering research, analysis, and design. Extreme Loading® Technology (ELT) provides superior 3-D analysis and visuals, replacing current practices which rely on simplified analysis or artistic renditions.

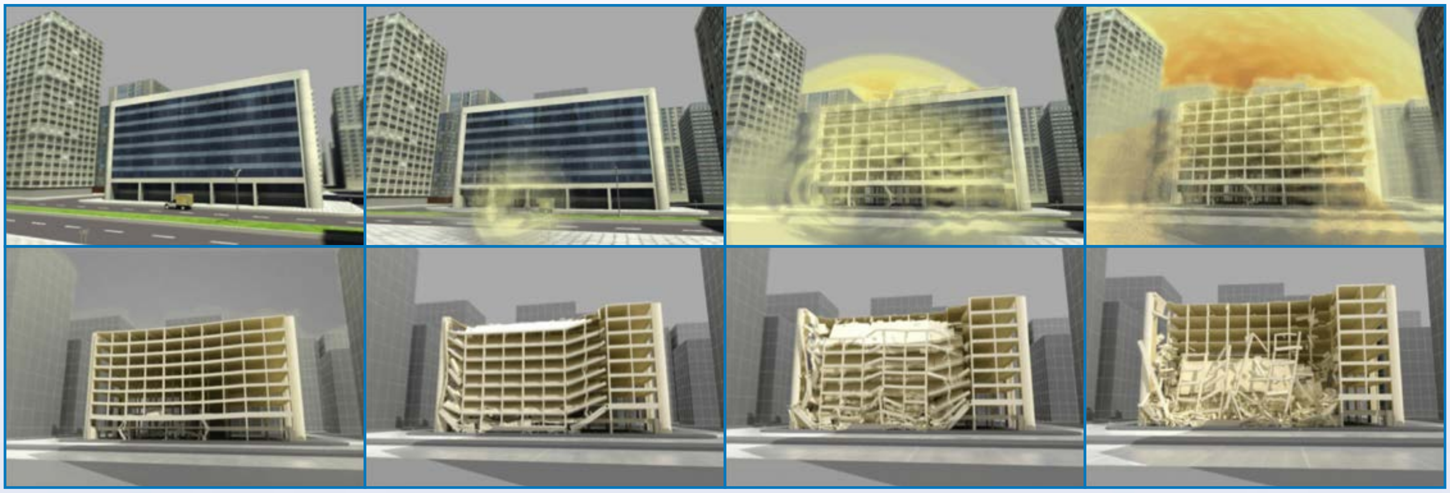
Protecting Assets Through Structural Engineering

Specialized Non-Linear Dynamic Structural Engineering Services

When it comes to specialized design, extreme loading conditions, or structural failures, ASI's team of veteran engineers and scientists provides a collective wealth of hands-on experience in engineering research, analysis, and design. Extreme Loading® Technology (ELT) provides superior 3-D analysis and visuals, replacing current practices which rely on simplified analysis or artistic renditions.

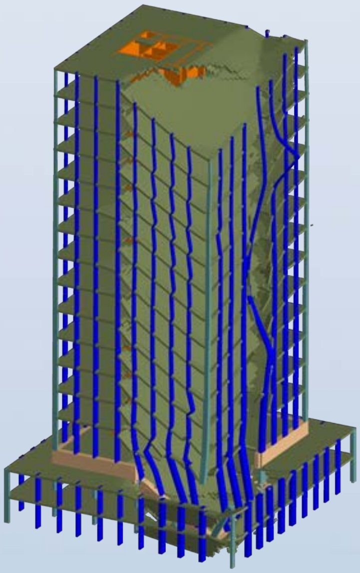
Blast Mitigation Engineering & Design Services:

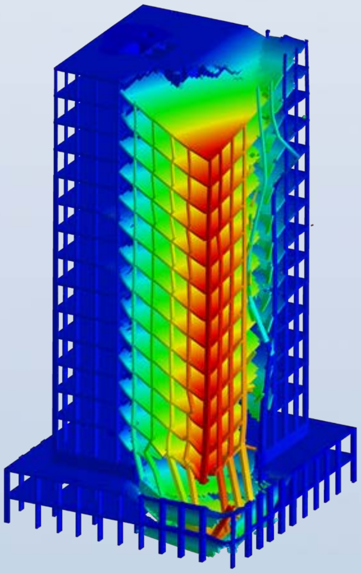
- Modeling and 3D simulation of structural and non-structural components behavior due to blast loads.
- Blast loads can be automatically generated using the UFC 3-340-02 Structures to Resist the Effects of Accidental Explosions or by custom generated pressure-time history.
- Blast loads can be imported from Computational Fluid Dynamic (CFD) analysis. (OpenFoam/Blast Foam)
- Assessment of structural vulnerability to blast loads.
- Glazing analysis due to blast loads.
- Assessment of debris and/or glass fragment velocity and dispersion.
- Determination of risk zones and stand-off distances.
- Recommendations for structure redesign and material cost saving, so as to resist provided blast loads and potential for progressive collapse.



Progressive Collapse (Disproportionate Collapse) Analysis Engineering & Design Services

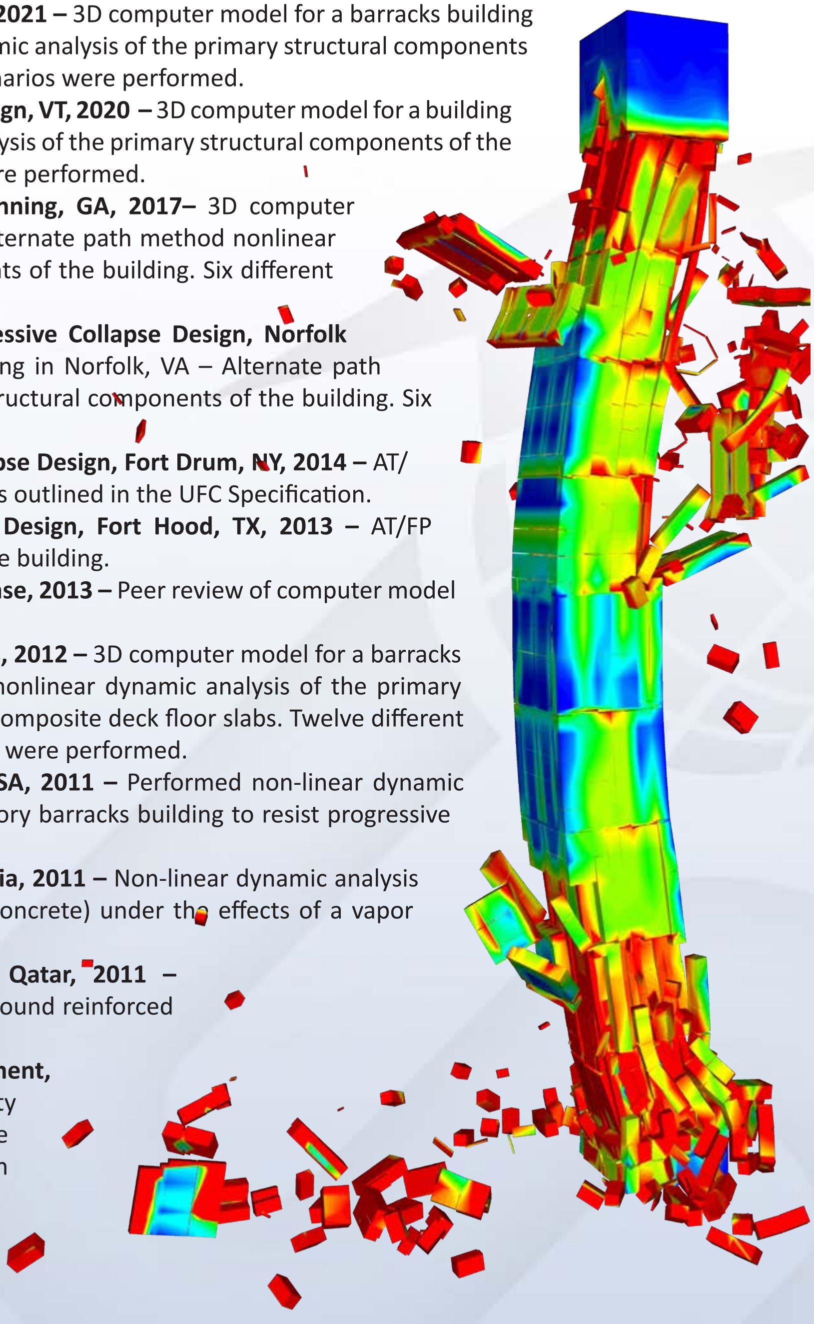
- Modeling and 3D simulation of new of existing structures subjected to single/multiple loading bearing member removal scenarios.
- The analysis takes into consideration the non-linear effect of structural slabs.
- P-Δ and P-δ is automatically considered in the analysis.
- Plastic hinge formation is an output not an input in the analysis.
- Infill un-reinforced and reinforced masonry walls are considered in the analysis if needed with true brick and mortar joints.
- Debris loading is automatically considered in the analysis.
- Membrane and catenary action are automatically considered in the analysis
- Recommendations for structure redesign/retrofitting and material cost saving to resist potential for progressive collapse.





Recent Protective Design Projects

Blast, Progressive Collapse, & Anti-Terrorism Force Protection



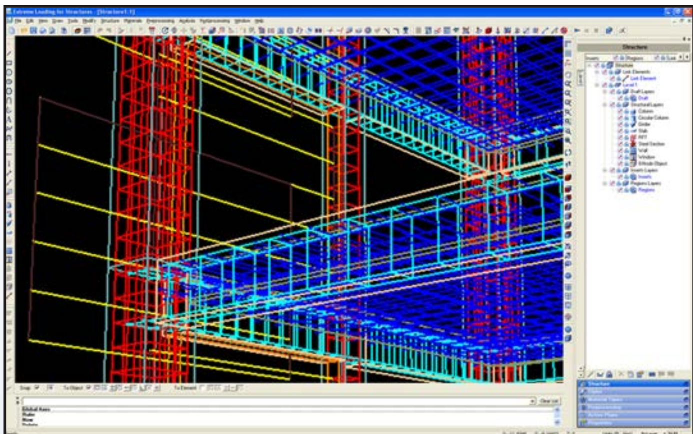
- **Fence Barrier Structural Vulnerability Assessment, Damam, Saudi Arabia, 2022 –** 3D computer model for a reinforced concrete wall used by the owner as fence around a maximum-security facility. The behavior of the wall under blast loads generated from a 1000kg TNT charge weight with a standoff distance of 50m was evaluated as well as the behavior under a vehicle impact weight a weight of 2 tons traveling with a speed of 80km/hr.
- **Building 1063 AT/FP Analysis & Design, Fort Sill, OK, 2021 –** 3D computer model for a barracks building in Ft. Sill, OK – Alternate path method nonlinear dynamic analysis of the primary structural components of the building. Twenty different column removal scenarios were performed.
- **Army Mountain Warfare School AT/FP Analysis & Design, VT, 2020 –** 3D computer model for a building in VT – Alternate path method nonlinear dynamic analysis of the primary structural components of the building. Nine different column removal scenarios were performed.
- **Building 399 Progressive Collapse Desing, Fort Benning, GA, 2017–** 3D computer model for a barracks building in Ft. Benning, GA – Alternate path method nonlinear dynamic analysis of the primary structural components of the building. Six different column removal scenarios were performed.
- **Unaccompanied Unelisted Personal Housing Progressive Collapse Design, Norfolk VA, 2016–** 3D computer model for a barracks building in Norfolk, VA – Alternate path method nonlinear dynamic analysis of the primary structural components of the building. Six different column removal scenarios were performed.
- **Soldier Family Critical Care Facility Progressive Collapse Design, Fort Drum, NY, 2014 –** AT/FP analysis for truss roof system to meet requirements outlined in the UFC Specification.
- **Company Operations Facility Progressive Collapse Design, Fort Hood, TX, 2013 –** AT/FP analysis and design for a CFS curtain wall system of the building.
- **Airmen Dormitory Building , Westover Air Reserve Base, 2013 –** Peer review of computer model analyses and the associated UFC code checks.
- **UEPH Barracks Progressive Collapse Design, Ft. Lewis, 2012 –** 3D computer model for a barracks building in Ft. Lewis, WA – Alternate path method nonlinear dynamic analysis of the primary structural components of the building, including the composite deck floor slabs. Twelve different load bearing wall, post and column removal scenarios were performed.
- **Fort Bragg Barracks Progressive Collapse Design, USA, 2011 –** Performed non-linear dynamic analysis of the composite deck floor system of a 4-story barracks building to resist progressive collapse.
- **ARAMCO Vapor Cloud Blast Assessment, Saudi Arabia, 2011 –** Non-linear dynamic analysis of three structures (masonry, steel, and reinforced concrete) under the effects of a vapor cloud explosion (VCE).
- **Underground Vault Blast & Impact Assessment, Qatar, 2011 –** Performed non-linear dynamic analysis of an underground reinforced concrete structure against impact & blast.
- **Women's Residence Hall Vulnerability Assessment, University of South Carolina, March 2010 –** Vulnerability assessment of a 7-story reinforced concrete structure as all non-structural walls were demolished with machines moving in the structure.
- **Ft. Hood WIT Barracks Progressive Collapse Design, USA, 2010 –** Non-linear dynamic progressive collapse analysis (UFC 4-023-03) of a 5-story barracks building consisting of a cold formed steel stud bearing wall system.
- **Titan Tire-Testing Facility Structural Vulnerability Assessment, Illinois, USA, 2008 –** Risk evaluation of an industrial manufacturing plant under the effects of explosion of one its large off-road tires in its tire testing facility.
- **Saint Francis Central Hospital Structural Vulnerability Assessment, Pittsburgh, USA, 2008 –** Evaluation of the potential of failure for the building after an incomplete demolition under the effect of high winds.
- **Fairwinds Tower Structural Vulnerability Assessment, USA, 2007 –** Identification of risk zones for all columns in the 48 story tower. 3-D non-linear dynamic analyses to estimate the potential of progressive collapse. Glass damage analysis for different impact scenarios and glazing materials.

The Practicing Engineer's Advanced Analysis Tool

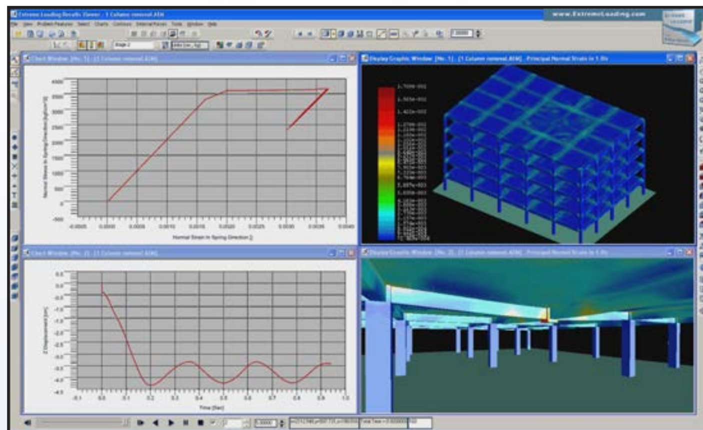
Advanced Nonlinear Dynamic Analysis for Structural Engineers.

Designing to real-world conditions and real-world threats is becoming an increasingly common requirement. This presents challenges for engineers tasked with the design and analysis of structures subjected to blast, seismic, high wind, and progressive collapse loading requirements. The result is that buildings that are not only built stronger but also greener. Extreme Loading® for Structures is the first advanced nonlinear analysis tool designed specifically for practicing engineers. It delivers a high-end structural analysis capability in a practical and engineer-friendly package.

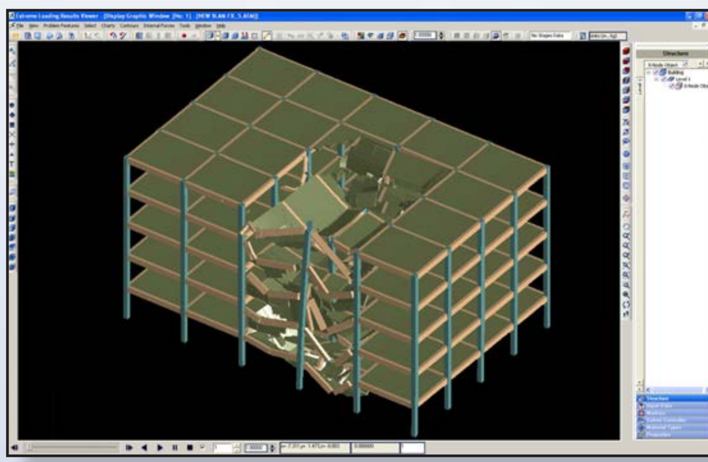
Extreme Loading® for Structures (ELS) allows designing to deliver economical and robust performance based designs, rather than taking a costly prescriptive code approach. Showcasing a recent white paper written regarding progressive collapse analysis shows that ELS can save up to 40% on the structural system.



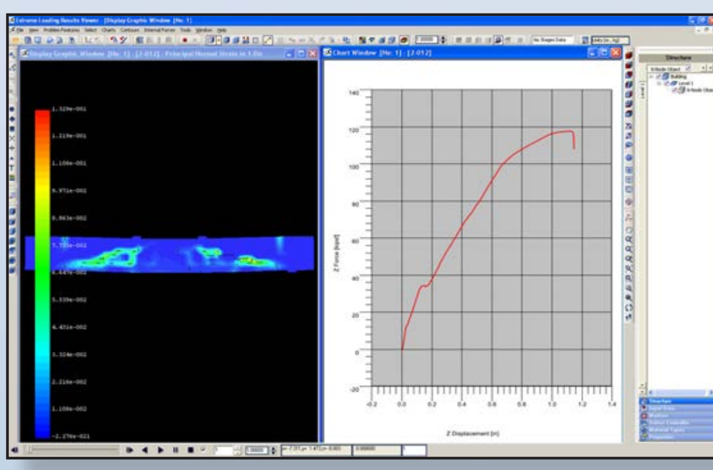
Custom Reinforcement



Automatic Yielding of Reinforcement



Automatic Crack Propagation & Separation

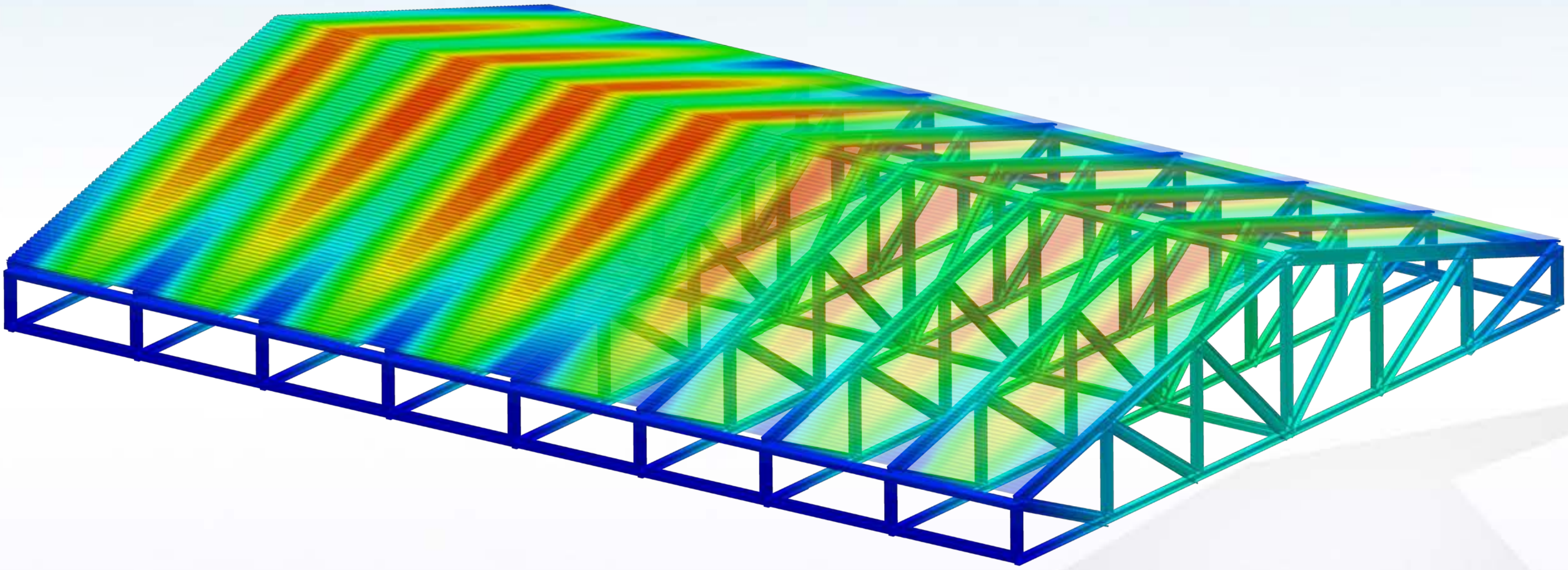


Stress Contour & Displacement Chart

Extreme Loading® for Structures Features:

- Easily model and analyze columns, slabs, girders, reinforcement, & connections.
- Import all structural components and reinforcement from Revit® Structure (BIM)
- No re-meshing required for connectivity between members or components.
- Nonlinear dynamic solver automatically considers hard to model phenomena such as crack propagation & separation of elements.
- Create internal force diagrams, Eigen modes, contour diagrams, and charts.

EXTREME LOADING® FOR STRUCTURES



VERIFICATION SAMPLES

Samples are problems solved using ELS that discuss static, dynamic, blast, and progressive collapse cases. Most cases document a comparison of analysis performed using ELS with experimental results or analytical solution using other analysis methods or tools. Documentation and an ELS file are available explaining each case. You can use the ELS file to run the sample and view its output.

SOFTWARE TUTORIALS

Included with ELS are more than 20 video tutorials that take users through all of the steps required to create and analyze various models and analysis cases. These video tutorials are updated and added to on a regular basis and as new features are added.

SOFTWARE TRAINING

In addition to the startup materials that come with each license of Extreme Loading® for Structures Software (ELS), users will benefit from completing the Extreme Loading® for Structures Certification program. Training modules include:

- Structural Vulnerability Assessment
- Blast Analysis
- Progressive Collapse Analysis
- Seismic Analysis
- Forensic Engineering
- Performance Based Design

For more information on Training visit https://www.extremeloading.com/customer-services-support/els-certified-training

ASI PORTAL

From the new ASI User Portal, Licensed ELS Users have 25-7 access to Software Updates, Tutorials, Quick Start Guide, Modeler Manual, Blast Manual, Viewer Manual, Theoretical Manual, Technical Reference Manual and the ability to upgrade or renew their license.

ADDITIONAL INFORMATION OR PURCHASE

For more information or a quote for Extreme Loading® for Structures visit www.extremeloading.com or call us at 1-919-645-5090.

SYSTEM REQUIREMENTS

Minimum:

-**Operating System**: Windows 10 & 11 (All 64 bit only)
-**Hard Disk**: 1 GB for Installation
-**Memory**: 1 GB RAM
-**Processor**: 64bit-Processor
-**Graphics Card**: With OpenGL 4.4, VRAM 2GB

Recommended:

-**Operating System**: Windows 10 & 11 (All 64 bit only)
-**Hard Disk**: 1 GB for Installation
-**Memory**: 32 GB RAM
-**Processor**: 64bit-Processor with Multiple Cores
-**Graphics Card**: With OpenGL 4.4, VRAM 4GB or Higher

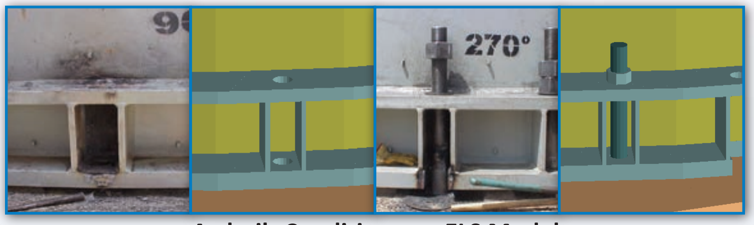
Yanbu Deethanizer Retrofit

Easily evaluate as built conditions & provide rapid solutions.

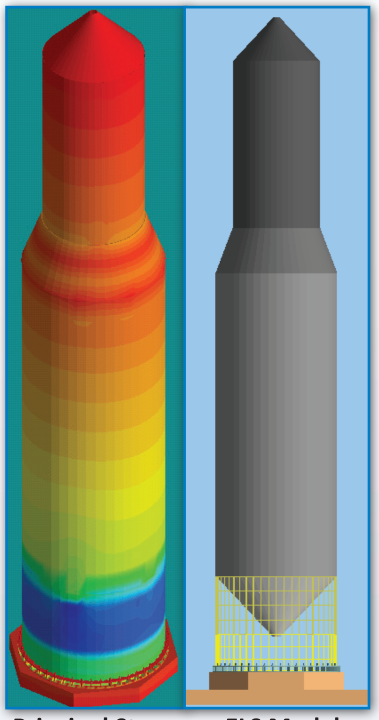
Problem—During the construction process of a deethanizer vessel, several design mismatches between the anchor bolts and base plate holes were observed. To complete the installation process, the vendor widened and slotted nine holes in the base plate and removed three anchor bolts. In addition, several anchor bolts were damaged and several others were subjected to excessive heat during the torching/cutting of several bolts. This raised concern about its safety and structural integrity.

Analysis—ASI was tasked to provide a comparative model and analysis of the structure using our in-house structural analysis software, Extreme Loading® for Structures. The objective was to compare the as-designed case with the damaged as-built case with regard to wind and seismic loading.

Conclusion—ASI created a 3-D model and explicitly modeled all damaged portions and compared the behavior with the designed case. Based on the analysis, ASI was able to assure the client that the as-built structure met the safety requirements for design loading conditions.



As-built Conditions vs. ELS Model



Principal Stress **ELS Model**

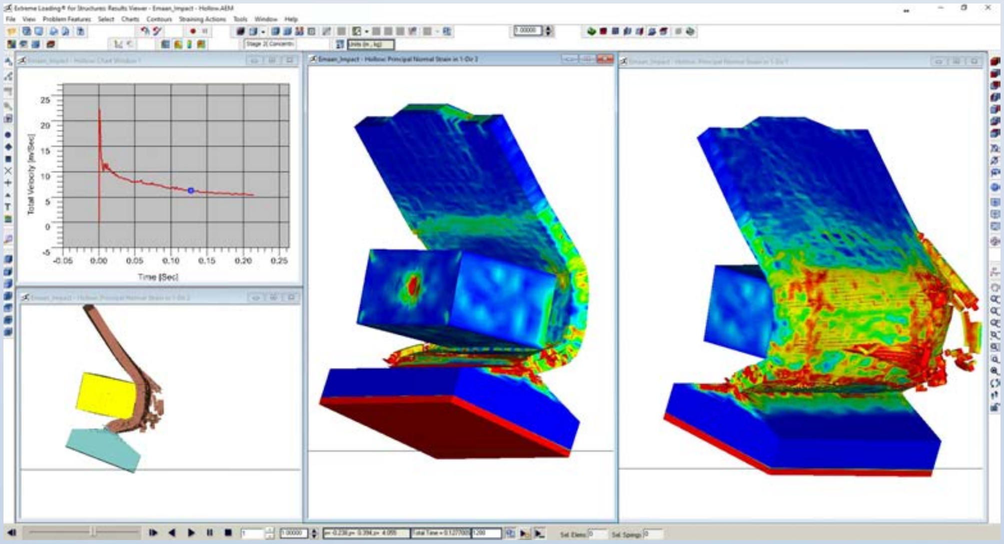
Anti-Ram Barrier Design

Dynamic analysis of vehicle collision on structures.

Problem—A secuitry facility has a secuirty fence constructed from Pre-Case reinforced concrete wall on the peremeter of their facility. It was required to test the fence under a scenario of a vehicle impact traveling with a speed of 80km/hr and see if the fence is capabale of preventing the the vehicle from entering the facility. The pre-cast wall will be assessed for blast loading and vehicle impact loading. For the purpose of this vulnerability assessment only one wall will be considered and no interaction between the surrounding walls.

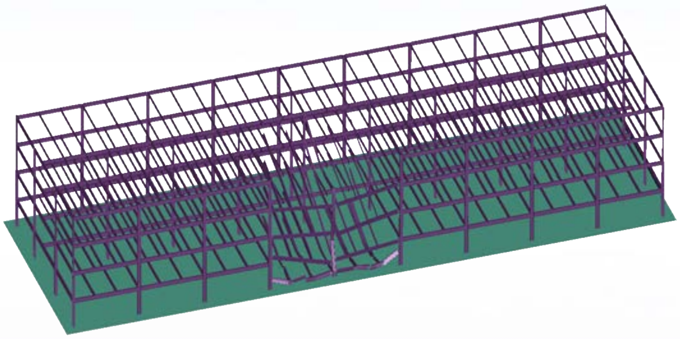
Analysis—ASI is tasked to perform structural vulnerability assessment for a pre-cast reinforced concrete wall utilizing ASI expertise. ASI is using their proprietary Extreme Loading for Structures Software (ELS) to assist with the structural vulnerability assessment for the pre-cast wall.

Conclusion—The wall suffered significant damage due to a vehicle impact. However, the wall was able to stop the vehicle from introduing the facility.

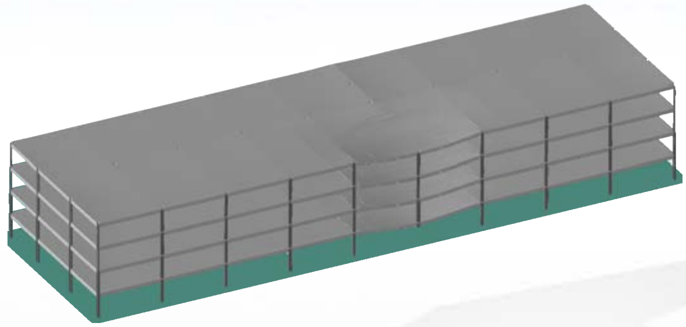


Reducing Cost on Progressive Collapse Requirements

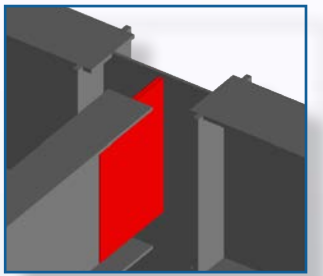
Design safer & greener by considering the entire structural system.



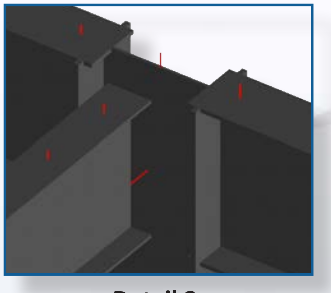
Model 1: Nonlinear frame analysis results.



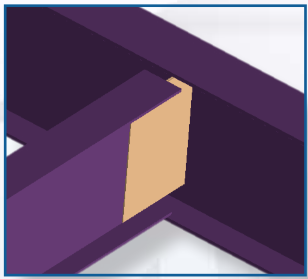
Model 2: Nonlinear frame & slab analysis results.



Detail 1: Partially restrained beam-column connection



Detail 2: Perfectly hinged connection



Detail 3: Partially-restrained main-secondary beam connection

Alternate Path Progressive Collapse Analysis:

In recent years progressive collapse analysis has materialized into explicit requirements for redundancy in building codes all over the world. Although progressive collapse is a nonlinear dynamic procedure, progressive collapse codes permit the use of linear static analysis with load factors.

In many cases a simplistic procedure is used, which models only linear beam and column elements. This neglects the contribution of walls and slabs which leads to uneconomic and/or unconservative results. Walls and slabs may be considered secondary members in other types of analysis but in progressive collapse analysis, walls and slabs often behave as primary members with slabs carrying load though membrane action and walls providing alternate load paths.

The cost savings is dramatic. In the comparison study, ASI found that analysis using simplified finite element linear and nonlinear analysis suggested a significant increase in the weight of the steel frame in order to satisfy the UFC progressive collapse code requirements. Using more advanced analysis, like AEM method shows that the original design is safe and there is no increase in weight required to satisfy the code requirements. Here ELS allows for a significant gain in economy & stability.

Analysis	Structure Weight	Percent Increase Required
SFEM Linear	108.7 Tons	80%
SFEM Nonlinear	78.2 Tons	34%
ELS	**58.2 Tons**	**0%**

Weight of longitudinal steel moment-resisting frame resulting from design using different numerical analysis methods.

Benefits of ELS for Alternate Path PC Analysis:

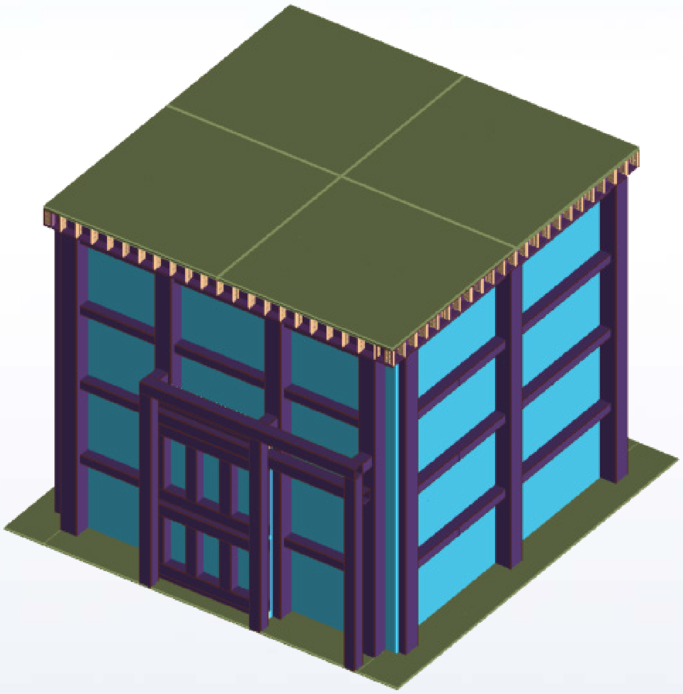
- Dramatically reduced modeling & analysis time.
- No iterations required due to instability.
- No "penalty factors" due to simplified analysis.
- More realistic & economic design due to the consideration of all structural components and connections.

EXTREME LOADING® FOR STRUCTURES

Sub-Sea Test Cell

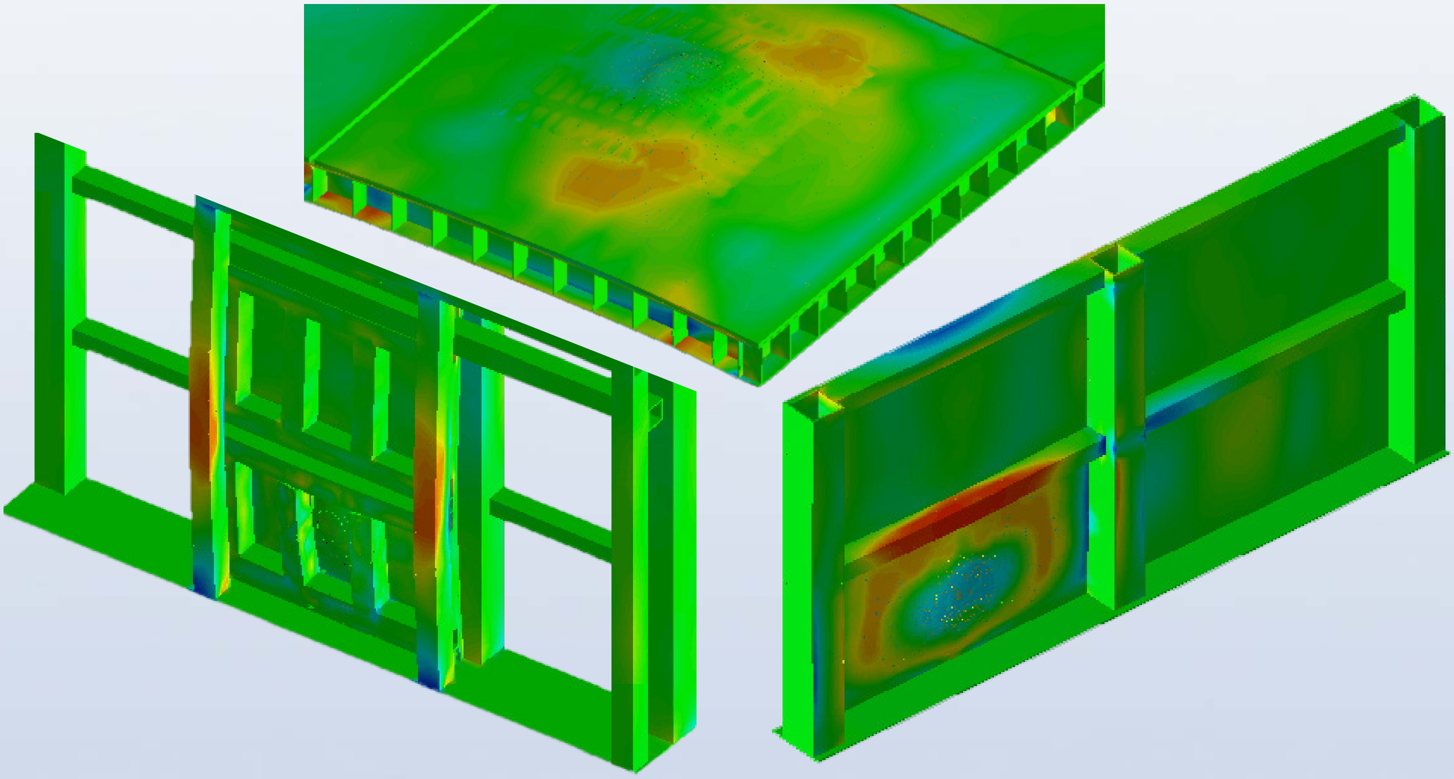
Performance-Based Design For Structural Optimization

This project was completed in 2012 in cooperation with Eyeington Enterprises, Inc., as part of a series of specialized technical consultations provided for Halliburton. The project involved analysis of a petrochemical testing structure, referred to as the Sub-sea Test Cell, subjected to extreme loading conditions. The loading scenarios considered included a large hydrostatic pressure as well as the impact of multiple sizes of fragments at high velocity. Additionally, the effect of blast pressure due to a confined explosion on the whole structure was evaluated. Both theoretical and empirically derived equations were used to assess fragment velocities and pressure/time-history loadings with reflections for various components of the test equipment.



Applied Science International (ASI) used its proprietary nonlinear dynamic analysis software, Extreme Loading® for Structures (ELS), to perform the analysis. This allowed the creation of a three-dimensional model of the entire Test Cell, as depicted in Figure 1.

This takes into consideration the overall performance of the structure rather than simplified component by component analysis done in traditional engineering analysis. The details of different connections and components were modeled using a high fidelity numerical model.



Using ELS, ASI predicted the potential failure modes for different structural components and different connections. This also permitted modeling the contribution of the secondary components in resisting the loads as well as the dynamic interaction between the walls, the slab, and the foundations. ELS takes into consideration material and geometric nonlinearities as well as post buckling behavior to ensure a realistic estimate of the overall performance of the structure when subjected to extreme loads that exceed the range of the linear elastic response of the structure.

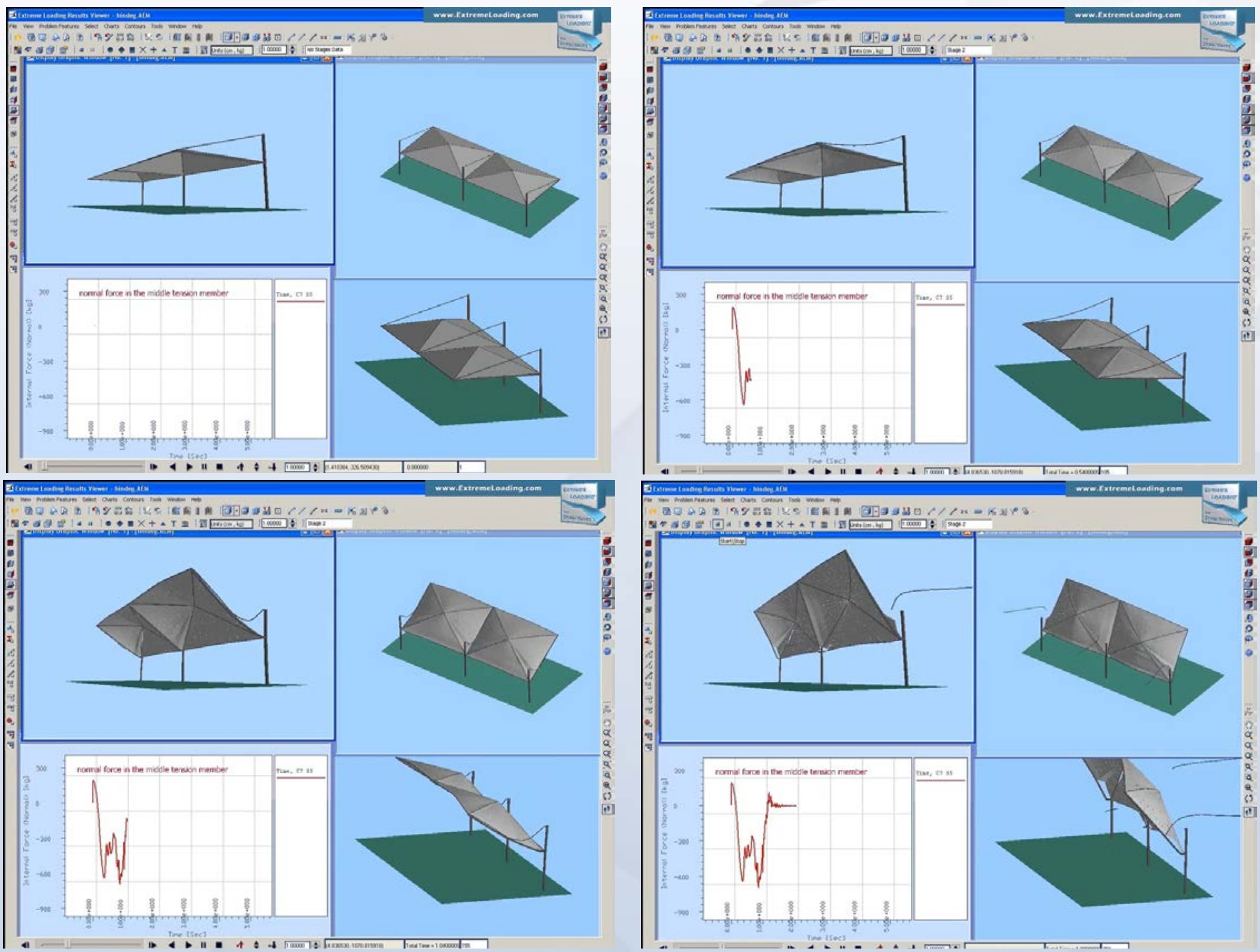
This performance-based method of design helped to optimize the design of structural components while meeting cost requirements and simultaneously ensuring a uniform and consistent factor of safety for all of the structural components.

Car Shade Structural Design

Dynamic Wind Analysis & Design Optimization

One of the cases where ASI expertise was used to optimize the structural design of a structural system was the case of newly developed innovative car-shade system. The producer had a successful product that has been installed in numerous locations. However, on installing the car shed at a certain location with relatively high wind loads it failed catastrophically.

Applied Science International used its in-house structural analysis software Extreme Loading® for Structures (ELS) to create a three-dimensional model for the car-shed taking all construction details and material properties into consideration. ASI engineers performed nonlinear dynamic analysis of the structure under the effect of the wind loading.



ELS Nonlinear Dynamic Analysis of the Car Shed Showing Failure Points

Based on the 3-D nonlinear analysis, ASI was able to show the sequence of failure for the specific wind load case. ASI engineers provided recommendations for strengthening specific diagonal members which were designed as tension members but which were subjected to compression loads in this specific wind load case.

www.appliedscienceint.com
www.extremeloading.com

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