SPECIAL REPORT

Homeland Defense
JOURNAL

Changing the Known Built World

Structural Security – The First Step to Physical Security

Special Report

CHANGING THE KNOWN BUILT WORLD

Structural Security – The First Step to Physical Security

A Handbook for Those Involved with Facility Planning and Security
Meeting the Needs of Homeland Security and Architectural and Structural Safety Demands

CONTENTS

Introduction

Applied Science International is dedicated to making the world a safer place by introducing a breakthrough in technology that redefines how buildings are constructed and protected to more readily withstand extreme loads resulting from terrorist attack, bomb blasts, earthquakes, hurricane force winds and other natural or unplanned disasters.

Imagine a truck loaded with the equivalent of 4,000 pounds of explosives parking at the curb near the center of a 9-story building.

Within 5 seconds of detonation the building lies in ruins, having totally collapsed. The explosion took out a supporting column which was enough to cause the failure of a main girder resulting in the progressive collapse of the building above this support.

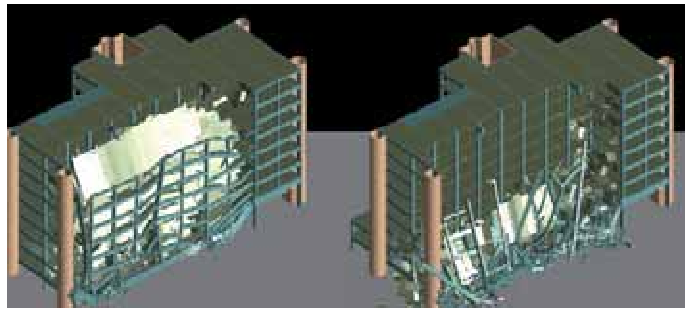
At the end of the day there are 168 confirmed dead and another 853 people injured – not from the blast itself, but from the collapse of the building.

In the face of these uncertain times, what can be done to protect the structure and ensure a safer workplace?

Until now, structural engineers have been limited to an approach called the “Finite Element Method,” or FEM to design buildings. The weakness of FEM-based models is that they bend but do not break; they deform but do not separate. Because FEM simulations have no separation of elements, it is not an accurate picture of what happens in reality.

Finally, after 12 years of research and development at Applied Science International (ASI), a new method termed the "Applied Element Method", or AEM, has been completed. A highlight of this new technology redefines how progressive collapse, seismic wave effect, high wind, glass and blast are viewed and analyzed by engineers.

Utilizing this new technology, ASI is able to look at every structural element exposed to the load and see first hand its predictable behavior. For example, engineers and architects can choose to change a column’s design to withstand different blast loads significantly mitigating the risk of collapse.



The building first mentioned in this article was the Alfred P. Murrah Federal Building in Oklahoma City. Using ASI modeling, we now know that if the steel reinforcing bars in the main concrete girder had been doubled, the structure would have better withstood the blast and many more people would have survived.

Knowing potential vulnerabilities of a design allows the making of more informed decisions on structural design and architectural layouts, determining building envelopes and perimeters, opting for alternate material selections, and even developing better security and safety procedures.

The progressive collapse of the Murrah building, the Twin Towers, and other structures has changed the way buildings are being designed, assessed and secured. AEM technology which creates a near virtual reality movie depicting the structure's behavior, has opened a new era in securing buildings through a more thorough and viable vulnerability assessment process.

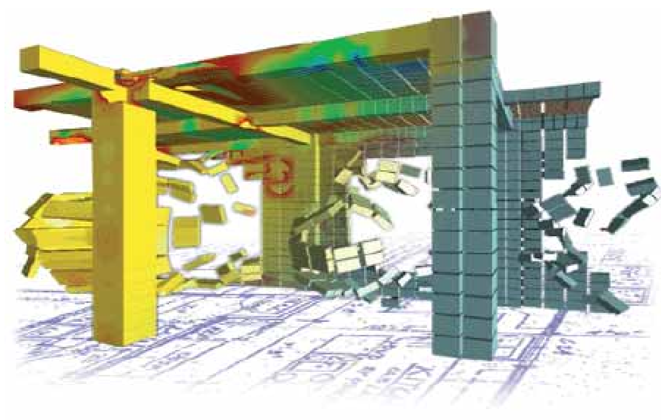
ASI vulnerability simulations come to life and are easily understood by engineer and non-engineer alike. Visualizing the assessment sets ASI’s method apart and gives owners and decision makers a clearer perspective on what they need to know to protect their people, their property and their future.

Overview

This breakthrough technology developed to analyze the behavior of structures exposed to terrorist explosions and unplanned or natural disasters is set to revolutionize how buildings are designed, remodeled and secured today.

The engineers and scientists at Applied Science International (ASI) have spent more than twelve years developing their cutting edge software technology – Extreme Loading for Structures (ELS) - that will help redefine how buildings are constructed and protected to more readily withstand extreme loads – ranging from earthquakes and hurricanes to bomb blasts and other disasters.

Collectively classified as extreme loading conditions, the amount and duration of the forces applied to a structure are what need to be understood in order to prevent the disastrous consequences that accompany the total collapse of a building.

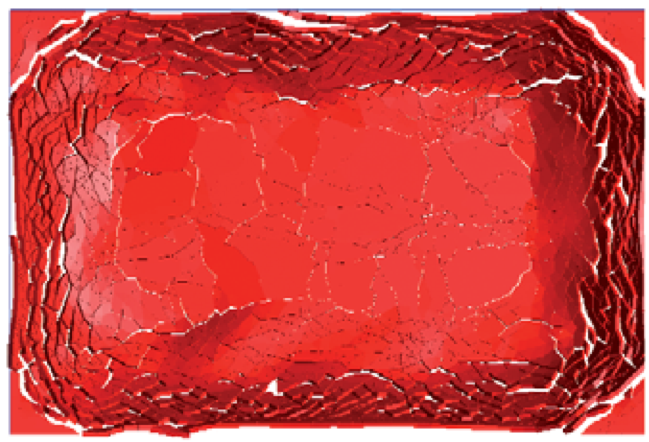


- Accuracy: from Table Look Up to Differential Equations & from Probability to Reality
- Variables: from a Fixed Set to Unlimited Possibilities
- Project Time : from Weeks to Days & from Months to Weeks
- Resources ($) = Time **x** Labor **x** Rate
- Results: from Indecision to Decision & from Inaction to Action
- Implementation : from Guess to Know to Do
- Security: from Not So Sure to Secure
- Safety: from A Priority to The Number One Priority

"For the first time, building owners, designers, architects, engineers, insurance underwriters, and security experts can view a full motion near-virtual reality video of what will happen before an event takes place, whether it's a bomb within a building's perimeter, an earthquake underneath it, or a hurricane assaulting it from the side. It is the world's only real-time progressive collapse analysis software and it can be used on any structure and at any phase – from pre-construction design of structures such as towers, sports arena and bridges to buildings scheduled for remodeling or demolition – there is no limit to its application," said Edward di Girolamo, ASI's Chief Executive Officer.

ASI has also greatly enhanced the "visualization" process by developing the Applied Element Method (AEM), a technology first introduced at Tokyo University in Japan, and developed by ASI for structural engineering.

Until now, progressive collapse models have been based on Finite Element Method (FEM) simulations which appear as melting plastic models with no separation of elements. This is not how it happens in reality. ASI's technology performs an engineering simulation of how each member or element can either contribute to or prevent the building's collapse. By simulating the event through a numerical process that is closer to physical reality than any other analysis method, ASI enables decision makers to take preventative measures for improved structural resiliency and to provide additional means to safeguard life and property.



"We have developed the AEM technology to analyze a broad range of materials such as glass panels, multi-layered glass systems and even building composite materials to determine their behavior under extreme loads. With this unique capability, modeling and simulating different scenarios gives decision makers the information needed for material selection, casualty assessment, hardening options and wind-blown hazard analysis," said di Girolamo.

In addition, the ASI team has developed a more accurate Vulnerability and Risk Assessment model. They have taken their technology and implemented it to give the decision makers additional insights into their building's behavior and its vulnerabilities. When used with other, more traditional assessment methods, ASI has made an impact on the client's structural, architectural, building envelope and other infrastructure and security decisions.

ASI has improved the risk assessment process and progressive collapse guidance now available in Federal Emergency Management Agency (FEMA) Risk Assessment documents and Department of Defense (DoD) guidelines for structural assessment. They have also recently provided the

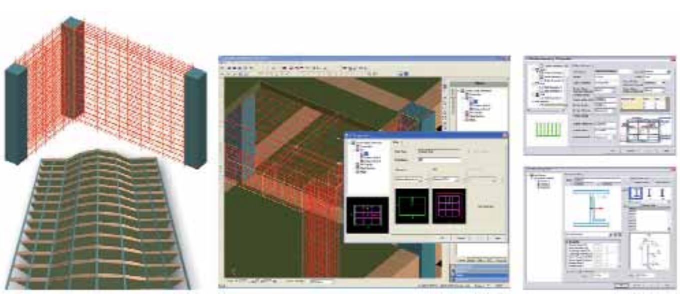
United States Army Corps of Engineers (USACE) Protective Design Center with relevant information for forthcoming progressive collapse guidance.

"Apart from greatly improving on earlier models, the AEM-based tools model and simulate threat scenarios – in hours not days. This rapid-prototyping capability allows the owner as well as the engineers, architects, and security firms to consider cost-effective performance-based design and risk mitigation options more quickly and thoroughly – in days not weeks as before. They can see their changes implemented in near real time," said di Girolamo.

"Visualizing predicted structural response simply brings a new level of understanding and informed decision making to constructing, retrofitting or securing a building through a modification of the structural design, a relocation of key assets, an extension of the building's perimeter, a changing the of the glazing, or the implementation of new security procedures. What is different from today's traditional assessment is that by seeing the potential consequences of a threat scenario decision makers are more likely to be motivated to action as they incorporate this informed decision making process into their thinking."

PART ONE
Protection through Prediction

"Applied Science International (ASI) is changing the way buildings are designed by delivering an increased understanding of the building's structural behavior. Through an affiliation and collaboration with numerous universities across the United States and internationally, ASI's own staff of seasoned engineers has extended advanced structural analysis to new dimensions previously unimaginable."
ASI CEO Ed di Girolamo



"It is an excellent tool. It accurately models a structure and does it much more quickly than other models and without the need of a mainframe computer."
Frank Ehrman, Security Consultant with Raleigh, N.C.-based Security Management Consulting

Most structures that have been built to date have been designed using a technology developed in the 1940s and known as the Finite Element Method. FEM models bend but do not break. No one could have imagined back then that structural engineering practices would evolve into advanced engineering simulations. And because of that FEM algorithms do not easily adapt to simulation technology the way AEM was designed to do from the beginning.

CASE STUDY
BLAST MODELING AND MITIGATION

Dr. Antonio Nanni, Professor and Chair of the Department of Civil, Architectural and Environmental Engineering at the University of Miami, is involved with two security-related projects using the ASI numerical approach as compared to solutions produced using the conventional FEM method.

One project – the Repair of Buildings and Bridges with Composites (RB2C) – is a National Science Foundation Industry-University Cooperative Research Center and an integral part of the Center for Infrastructure Engineering Studies). RB2C involves blast tests on concrete slabs strengthened with composite materials to study mitigation effects. The blast tests are conducted in an underground mine and the results were compared to models using ASI software. "The results were very positive," said Dr. Nanni.

Another much larger project involves the Tenza Bridge, located about 50 miles south of Naples, Italy. It received initial funding from the Technical Support Working Group (TSWG), the U.S. national forum that identifies, prioritizes, and coordinates interagency and international research and development requirements for combating terrorism.

The team has completed the characterization of the structure, conducted specific material testing and material characterization and run a series of theoretical scenarios using ASI's numerical method. This preliminary stage is slated to be followed by an experimental stage involving the placing of explosive charges and performing other field work determined during the AEM modeling phase. Finally, the bridge will be completely demolished and the site cleaned up. Additional funding to complete the project is being sought from the European Union.

Next Generation Modeling

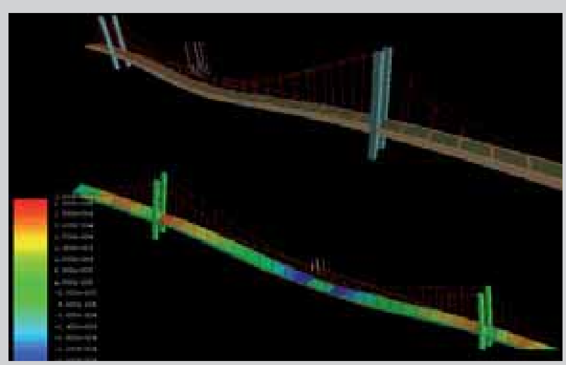


Illustration of a Suspension Bridge with a Moving Load

continues on page 5

Dr. Nanni said that traditional modeling using FEM has a number of limitations and until recently the next generation of real modeling programs were computational fluid dynamic (CFD) models which are very complex. Producing a model for a complex structure might take two days to run even with the aid of a super computer. Additionally, there is another problem: most of these CFD models and their attached programs are proprietary thus severely limiting the access researchers and the wider community have to them.

"That is why the ASI model is so exciting. We have been working with ASI on the implementation of material property constituents – both for steel and concrete – which change depending on the strain to which they are subjected.

"There is no doubt that the ASI software is impressive and has a lot of very good features. What we liked very much was its speed. If you have to run hundreds of simulations it makes a dramatic difference. Its simplicity of approach, speed of completion of the job and quality of output really make it very attractive for us.

"However, the most important aspect of the ASI software is the validation of what is taking place. It shows what needs to be done to make sure that the experimental campaign matches the analytical one and that the predictions made really can be confirmed by the experimental results.

"It is a material system that in terms of cost and in terms of application can be extremely economical. There are obviously different levels of mitigation but I think if one were to have a portfolio of options, the mitigation via "hardening" could become really viable," said Dr. Nanni.

"ASI deserves credit both for the technical quality of their software and also for their level of openness in making it available."

Applied Science International has developed this new process, the Applied Element Method, to model structures closer to reality than ever before. AEM structures break and separate as they would in a progressive collapse. Models can even be developed for individual elements to understand how they respond to extreme loading.

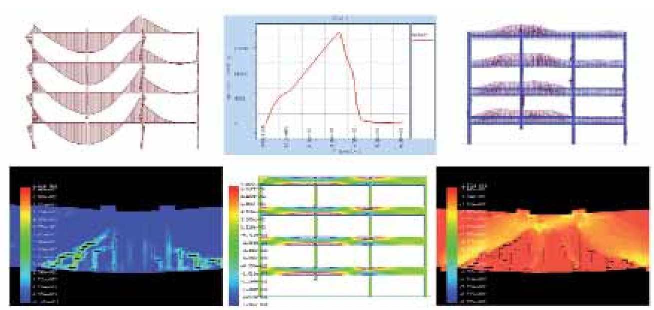
For instance, as mentioned in the Overview, ASI has developed a unique glass fragmentation module that can be modified according to the materials and system configuration of glass panels – this capability is found nowhere else addresses the issue of glass fragmentation, a danger second only to the blast itself.

AEM has been integrated into a software toolset called Extreme Loading® for Structures to do seismic analysis, extreme wind loads, progressive collapse analysis and other advanced engineering analyses of structures.

ELS is an advanced engineering software at an affordable price for structural and civil engineers who design steel, concrete, reinforced concrete, masonry walls and other composite materials. Its features far exceed today's FEM tools in modeling and processing speed, simplicity, accuracy and capability. Though widely used in Research and Development programs at universities, ASI will release a new version of ELS for Structural Engineering and Architectural firms early this Fall.

Extreme Loadings Advantages

- Provides insight into all stages of collapse
- Includes effects of pressure waves – providing comprehensive blast modeling
- Accurately analyzes various explosion scenarios
- Offers 2-D and 3-D analysis
- Presents structural response in real time
- Includes effects of windows, interior walls and other non-structural elements
- Identifies impact on surrounding structures
- Provides rapid modeling time



Extreme Loading® Technology

ASI has also implemented Extreme Loading® technology using the Applied Element Method to analyze the effects of various blast scenarios. They provide this as a service to building owners, on existing structures or new construction answering key safety and security questions

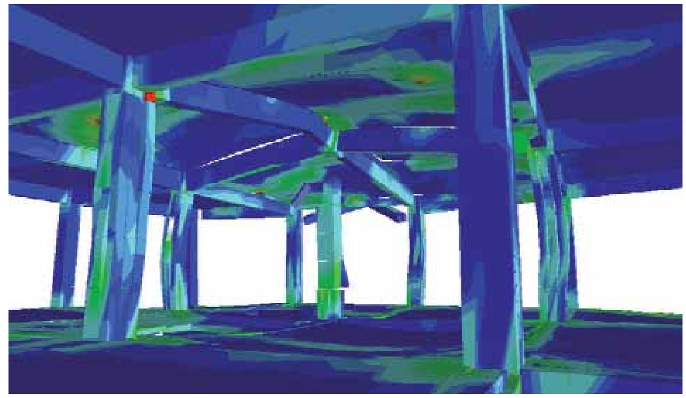
ASI's risk mitigation process employs their technology to help identify a building's vulnerabilities thereby allowing reinforcement of critical elements and preventing building collapse. It allows architects, designers and engineers to analyze and simulate structural failure when confronted by a wide array of man-made and natural hazards while still early in the design cycle with full-motion virtual reality.

Simulating a wide range of scenarios, the software can predict the effect of a terrorist bomb or the damage from an earthquake. If a building will collapse, how it would collapse, how long this will take, what will happen to nearby buildings and what the affected perimeter will be, are all outcomes that can be generated by its use. This information often affects critical infrastructure considerations, egress plans, security procedures and other safety related areas providing more cost-effective strategies for minimizing casualties and damage to property.

In all cases it shows the impact on the structure enabling design modifications to be made or structural improvements such as hardening to be carried out with the end result being much safer buildings.

ELS – the software for Structural Engineers

- Redefines how buildings are constructed so they may more readily withstand extreme loads resulting from earthquakes, high winds, progressive collapse and other natural disasters or extreme loading events.
- Significantly increases the capability of engineers to evaluate structures and accurately determine a cost effective strategy for minimizing damage to property and people
- Introduces a new level of advanced engineering analysis with ELS's AEM solver and superior GUI. Both allow the study of effects of a variety of loads on structures including high winds, seismic loads, blasts and progressive collapse
- Saves time modeling. Its world class GUI that significantly reduces the time needed to build projects and uses much less computing resources to run analysis in hours not days or weeks.



Extreme Loading® for Structures Features (for Engineers only)

ELS does nonlinear static and dynamic analysis of 3D models for a variety of Structural Materials. Analyze steel, composite materials, reinforced concrete, and brick structures enabling the creation of true 3D models of structures that include section detailing. By using ELS state of the art Graphical User Interface (GUI), the user is able to intuitively create comprehensive, detailed 3D models including details that are crucial to its performance. Models are pre-meshed and connected, thus no time is lost adjusting the model mesh and its connectivity.

When applied to a structure - this technology gives the owner, engineer, project manager, general contractor, insurance underwriter and other interested parties a full-motion virtual reality picture of the structure's integrity and behavior during extreme loading events. In addition to ELS, ASI uses its AEM technology and provides a service to building owners for demolition and deconstruction projects, blast analysis and glass fragmentation, and vulnerability assessments and risk mitigation unlike any other. ASI has achieved a new level of protection through the prediction of diverse scenarios and threats.

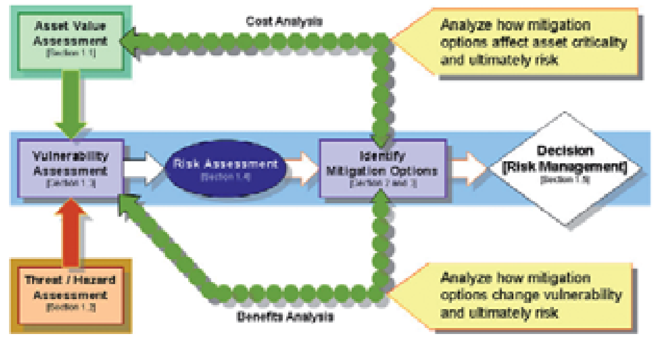
The Applied Science side of ASI

The company has taken this technology and applied it to today's traditional Vulnerability Assessment and Risk Mitigation processes allowing it to develop a new and more comprehensive approach. It has revisited traditional practices for performing vulnerability assessments and redrawn the playing field its way by increasing the importance of the role of the structure in the overall assessment process.

Since the dawn of time, man has retreated to the cave, the castle, the fort or the stronghold for protection and to defend himself against his adversaries. Today is no different. The all too recent events of Oklahoma City, the Pentagon, and the World Trade Center stand as tragic examples of structural collapse induced by extreme loads.

Once a building has been compromised, the internal infrastructure which includes electrical, heating and air conditioning, security, egress systems, fire alarms and sprinkler systems, information technologies (IT), surveillance and communications systems to name just a few, are often compromised as well.

Today's "traditional" (and outdated) assessment practices consider the structure, its architecture and the building's envelope as checklist items because ASI's technology did not exist until recently.



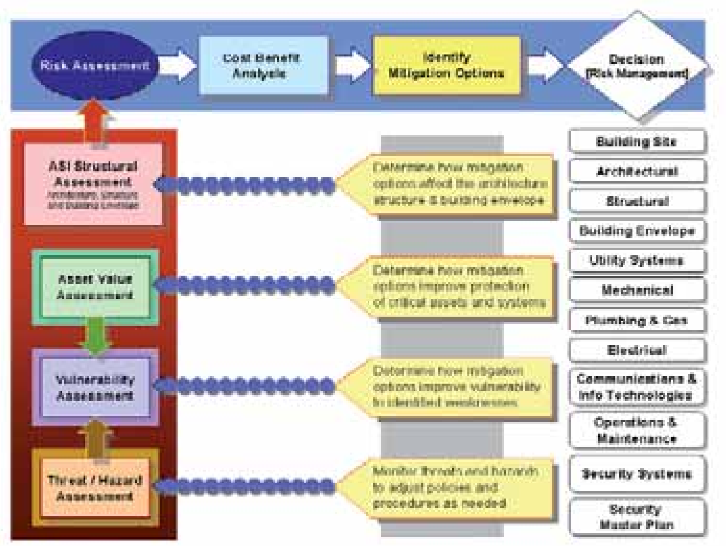
Traditional Risk Assessment Process

The traditional risk assessment process considers structural components as part of the vulnerability assessment as a checklist which yields certain values. Existing commercial software depicts pressure contours in different colors on a building to indicate most likely areas for some level of failure given a blast location. Many structural software providers claim they do progressive collapse analysis using FEM based technologies, but fall short of providing accurate simulations of the event. Therefore, the structural checklist has all but become obsolete being neither conclusive nor illustrative of reality. ASI technologies on the other hand visually demonstrate to the owner what will happen in any given scenario more quickly and with depictions that can be seen and acted on more readily.

	Armed Adversary	Improvised Explosive Mail/Pipe 1 to 5-lb	Suicide Bomber Briefcase 50-lb	Car Borne Explosive 500-lb	Van Borne Explosive 1000-lb	Truck Borne Explosive 2000-lb	Truck Borne Explosive 4000-lb	
Overall Structure	431	431	506	1134	1660	2450	2928	
Overall Tower TOTAL	175	175	226	512	746	1080	1282	Total
Structural System (Progressive Collapse)	10	10	10	40	90	160	200	Total
	10	10	10	10	10	10	10	Asset Value
	1	1	1	2	3	4	4	Threat Rating
	1	1	1	2	3	4	5	Vulnerability Rating
Primary Support Columns	10	10	10	40	120	200	250	Total
	10	10	10	10	10	10	10	Asset Value
	1	1	1	2	4	5	5	Threat Rating
	1	1	1	2	3	4	5	Vulnerability Rating
Secondary Support Columns	8	8	32	72	96	120	144	Total
	8	8	8	8	8	8	8	Asset Value
	1	1	2	3	3	3	3	Threat Rating
	1	1	2	3	4	5	6	Vulnerability Rating
Expansion Joint	9	9	36	81	108	135	162	Total
	9	9	9	9	9	9	9	Asset Value
	1	1	2	3	3	3	3	Threat Rating
	1	1	2	3	4	5	6	Vulnerability Rating
Underground Parking Garage	48	48	48	96	128	200	240	Total
	8	8	8	8	8	8	8	Asset Value
	3	3	3	4	4	5	5	Threat Rating
	2	2	2	3	4	5	6	Vulnerability Rating
Perimeter Less Than 15 Ft	48	48	48	120	120	160	160	Total
	8	8	8	8	8	8	8	Asset Value
	3	3	3	3	3	4	4	Threat Rating
	2	2	2	5	5	5	5	Vulnerability Rating
Glass Windows	42	42	42	63	84	105	126	Total
	7	7	7	7	7	7	7	Asset Value
	3	3	3	3	3	3	3	Threat Rating
	2	2	2	3	4	5	6	Vulnerability Rating

The traditional assessment evaluates the asset, threat and vulnerability and assigns a value based on checklist information and questionnaires. These values total to an overall value which is then colored by the presenter for effect – red depicts the greatest risk, orange a lower risk, etc. This is where ASI departs from the traditional assessment and generates a separate structural assessment.

ASI has taken their technology and modified the traditional approach by redefining how the structural checklists are used. The checklists provide a reasonable basis for asking questions in a site survey and for understanding the structural composition for existing structures. Once the building is modeled with the correct specifications and material composition, the rest becomes automatic and simulations are generated. The traditional approach with out the structural data provides only a limited portion of the information needed for a complete assessment. The structural assessment is also a key element in the overall risk assessment.



Assessing the Structure in Infrastructure

ASI's new vulnerability assessment method amplifies the structural assessment as an integral part and layer of the other three essential ingredients as illustrated above. This method does not use the traditional structural, architectural and building envelope checklists solely to determine the structure's vulnerabilities, but instead creates a separate structural analysis through modeling and simulation. The ASI structural engineer models the building and runs the scenarios specified by the owner, project engineer, and security consultant or project team. There is no guess work in determining the outcome of the extreme loading events – because the technology accurately depicts the predicted outcome and sequence of events.

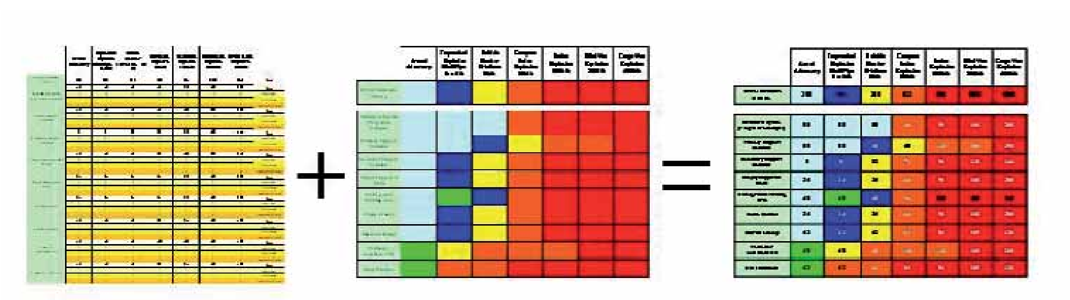
Once the analysis has been completed, the identified vulnerabilities are rated with colors according to the outcome of the simulations using a modified version of the structural damage tables employed by the DoD. The delineation of progressive collapse possibilities is further broken out because many buildings collapses are partial in nature. Partial and progressive collapse scenarios affect rescue efforts as the safety of first responders is taken into consideration.

Structural Integrity Ratings		
Very High		Very High Failure Potential. Potential for severe to catastrophic damage, frame collapse, and massive destruction. Doors and windows fail and result in lethal airborne hazards. Majority of personnel will suffer fatalities. Little left standing.
High		High Failure Potential. Heavy damage, unrepairable. Onset of structural collapse or partial collapse. Major deformation of primary and secondary structural members. Progressive collapse is possible. Collapse of non-structural elements probable. Glazing will break and is likely to be propelled into the building, resulting in serious glazing fragment injuries, but fragments will be reduced. Doors may be propelled into rooms, representing serious hazards. Majority of personnel suffer serious injuries. There my be up to 25% fatalities.
Medium		Medium Failure Potential. Moderate damage, repairable but expensive. Major deformation of non-structural elements and secondary structural members and minor deformation of primary structural members, but progressive collapse is unlikely. Glazing will break, but fall within 1 meter of the wall or otherwise not present a significant fragment hazard. Doors may fail, but they will rebound out of their frames, presenting minimal hazards. Majority of personnel suffer significant injuries. There may be less than 10% fatalities.
Low		Low Failure Potential. Minor damage, repairable. Minor deformations of non-structural elements and secondary structural members. Glazing will break, but will remain in the window frame. Doors will stay in frames, but will not be reusable. Some minor injuries, but fatalities are unlikely.
Very Low		Very Low Failure Potential. Minimal damage, repairable. Very low potential for failure exists. No permanent deformation of primary and secondary structural members or non-structural elements. Glazing may crack but will not break unless specifically targeted. Doors are reusable. Only superficial injuries are likely.
Negligible		Negligible Failure Potential. No potential for failure exist. Superficial damage, repairable. No permanent deformation of primary and secondary structural members or on-structural elements Glazing will not break unless specifically targeted. Doors are reusable. No injuries are likely.

Adapted from DoD UFC 4-010-01

The above table gives the level of damage with a color rating used to build the structural assessment. Once the structure has been assessed, the engineering findings are color coded for each threat and the vulnerable areas identified by the team. The structural assessment threats scenarios are organized across the top of the diagram similar to the traditional risk assessment in preparation for combining the two assessments.

In a traditional assessment, values are given to the threat likelihood, asset ratings and vulnerabilities. A structural matrix of the findings are depicted in color and overlaid onto the traditional assessment to create a significantly more informed presentation – one the owner can see and use to visualize the extent of damage or behavior of the building under specified conditions and scenarios.



Combined Traditional Assessment and Structural Assessment

Combining both the traditional assessment and the structural assessment yields the new table depicted below. Instead of coloring large numbers, the colors represent the level of damage and a truer picture of the threat emerges defining the impact on the facility or organization which is being evaluated.

	Armed Adversary	Improvised Explosive Mail/Pipe 1 to 5 -lb	Suicide Bomber Briefcase 50-lb	Compact Sedan Explosive 500-lb	Sedan Explosive 1000 -lb	Mini Van Explosive 2000 -lb	Cargo Van Explosive 4000 -lb
Overall Structure TOTAL	256	256	280	622	914	1370	1646
Structural System (Progressive Collapse)	10	10	10	40	90	160	200
Primary Support Columns	10	10	10	40	120	200	250
Secondary Support Columns	8	8	32	72	96	120	144
Simply Supported Slabs	24	24	24	64	96	160	200
Underground Parking Area	48	48	48	96	128	200	240
Comm Central	24	24	24	64	96	160	200
Entrance Ramp	42	42	42	63	84	105	126
Perimeter Less than 15 ft	48	48	48	120	120	160	160
Glass Windows	42	42	42	63	84	105	126

Combined Risk Assessment

The combined risk assessment now has information that needs a little bit of interpretation, but yields far more useful results than a three hundred page engineering report might yield. If the number value is low from the more traditional approach which focuses on the likelihood of the threat and the color is light blue indicating little to no damage on the structural assessment then there is little reason to consider that expensive mitigation planning, procedures or modifications to be made.

On the other hand if the numerical value is high and the color is red, the owner will quickly see the need for remedial action to protect the facility. These actions can either be decisions that change the design, the architecture, the building envelope or the security procedures – and all come with a price tag. And – what do you do when the threat number is high and the color is low or vica versa?

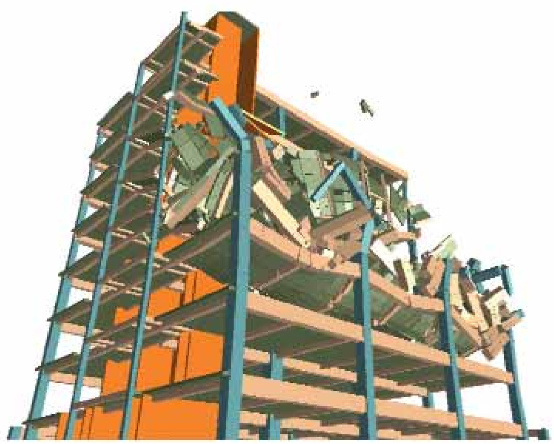
To answer that question, ASI has developed a decision matrix that assists the evaluation team in determining those areas of risk the owner should consider when applying resources to remediate the vulnerability or for providing some measure of incremental improvement within the budget to do so.

ARCHITECTURAL, STRUCTURAL, ENVELOPE ASSESSMENT

Vulnerability Assessment	LOW	MED	HIGH
1-166 167-333	No Procedural No Structural No Architectural No Envelope	Yes Procedural No Structural No Architectural Yes Envelope	Yes Procedural No Structural Yes Architectural Yes Envelope
334-500 501-666	Yes Procedural No Structural No Architectural Yes Envelope	Yes Procedural No Structural Yes Architectural Yes Envelope	Yes Procedural Yes Structural Yes Architectural Yes Envelope
667-832 834-1000	Yes Procedural No Structural Yes Architectural Yes Envelope	Yes Procedural Yes Structural Yes Architectural Yes Envelope	Yes Procedural Yes Structural Yes Architectural Yes Envelope

Decision Matrix

ASI developed this simple but unique decision matrix to help the assessment team interpret the meaning behind the combined risk assessment. As partners with the owners in the assessment process, they are able to make more informed decisions can be made affecting the cost and benefits related to improved security practices and procedures, potential structural and architectural improvements, and even the type of glass and landscaping needed for a safer building.



The New Structural Technology

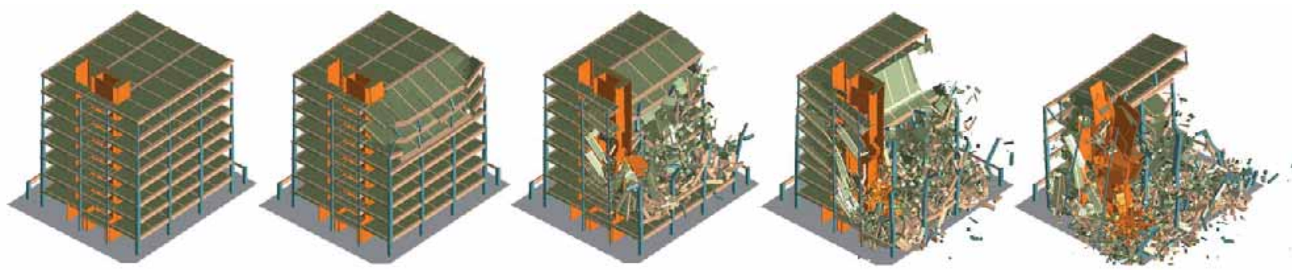
Unforeseen events such as major earthquakes, explosions, unexpected impact forces, or fire may subject a structure to extreme loading conditions during its lifetime that far exceed its original design. Unfortunately, in the past, the necessary factors in a building's design to resist such extreme loads were precluded either as a result of economic circumstances or because of the inability to accurately predict the outcome of such events.

Society has learned through very hard lessons in the last few years that this does not mean that such occasions will not arise. Furthermore, the safe evacuation of the building's occupants prior to its collapse, or subsequent rescue once collapse has occurred, becomes the paramount concern for both those trapped inside and those charged with saving them. A review of the casualties caused by major earthquakes around the world found that more than 90 percent of the death toll resulted from the structural collapse of buildings and bridges.

- What happens to those structures adjacent to the collapsing one when falling parts collide?
- What is the footprint affected by the collapse of a structure?

These questions are merely samples of what cannot be answered without having a mechanism to provide a valid prediction of structural performance when subjected to extreme loading.

That was the reason for developing the Applied Element Method (AEM)—which is the basis for the software program Extreme Loading for Structures.



Computer simulation is an important key in determining the performance of structures in extreme loading conditions, and yet predicting the accurate collapse behavior of structures using available numerical techniques and simulations has not been possible to date. Furthermore, because the word "collapse" means that the structure will not be able to resist any future normal loads, it was also not possible to predict whether the structure would fall down of its own accord or would remain partially intact prior to its demolition after being subjected to an unexpected extreme load.

Methods used for structural analysis are mainly based upon rules of continuum mechanics, such as the finite element method (FEM), an approach that cannot be applied to discrete elements. Therefore, continuum mechanics-based methods cannot be extended to simulate a collapse. Conversely, analysis methods based on rules of discrete material cannot be used to predict the behavior of continuum elements.

During a collapse situation, structures pass first through a continuum stage, and then through a discrete stage. Because of these factors, the computer simulation must follow both of these behavior stages in order to answer the following questions:

- Will the structure collapse in an extreme loading event?
- What is the mode of collapse of the structure?
- How long will it take for the structure to travel through to a complete collapse?

AEM for collapse analysis of structures

AEM is capable of predicting to a higher degree of accuracy the continuum and discrete behaviors of structures. Throughout twelve years of continuous development and testing, AEM has consistently proven itself to be the method that can best track the structural collapse behavior passing through the stages of the application of loads, crack initiation and propagation, element separation, element collision (contact), and collision with the ground and with adjacent structures. The method's degree of accuracy has been verified by numerous experimental and theoretical results to date. Literature surveys also indicate that no other simulation technology has a rate of performance comparable to that of AEM.

The AEM solver can accommodate the following aspects during analysis:

- Nonlinear material models for steel and concrete can be accommodated.
- All reinforcement details, including stirrups diameter, and concrete cover are easily considered.
- Analysis can include non-structural elements as well as structural elements such as glass windows or brick bearing walls.
- Separation, contact, and collision between elements are all taken into consideration.

- Special performance elements, such as interface or gap elements that are required in FEM, are not needed at separation or contact locations.
- The separation of structural elements and the collisions between elements are arbitrary at any location within the structure.
- Collapse simulation involves the use of advanced optimization techniques to solve large-scale problems using less memory size and shorter time.

In numerical simulations, it is widely-recognized that the modeling of complicated physical systems often requires more time on preparation than in performing the actual computation of results. Since the modeling process depends on the analytical method used, it is important for engineers to select the proper analysis method due to the complexity and time requirements necessary to create the model. Simplicity of structural modeling now becomes a key point in order to save time for revision and to assure a reliable degree of accuracy.

Collapse analysis simulations of the AEM can achieve many critical results. Most importantly, unlike FEM-based programs, the analysis can:

- continue to detect how the structure collapses
- monitor the collapse time
- determine the area of destruction around the building, and
- assess the effect of a collision of the failed structure with adjacent structures.

Collapse Simulation of Alfred P. Murrah Building

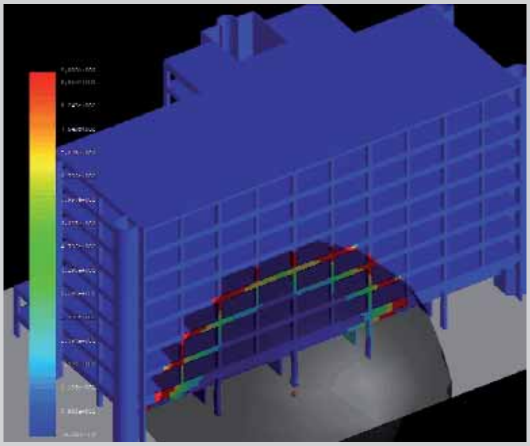
AEM can easily be used for an accurate analysis of the collapse of structures.

In 1995, the Alfred P. Murrah Building in Oklahoma City, was subjected to the effects of 4,000 pounds of explosives. Using this as a verifiable control, the collapse was simulated using the Extreme Loading software to predict the structure's behavior when subjected to such extreme loadings.

There is no need to know any information about the collapse history before solving the model. And, a free-field pressure wave—which is a function of explosives' weight, location, and time of wave arrival to the structural elements — can easily be considered. The pressure wave is assumed perpendicular to the loaded surface. The time step applied for calculations is 0.001 seconds to accurately follow the wave front. The user does not have to guess which element will be destroyed by this wave. In fact, the program automatically determines the elements subjected to a direct pressure wave from the blast. Additionally, multiple explosives and locations can be considered, location and time of explosive are arbitrary, and time lag between explosives is permitted.

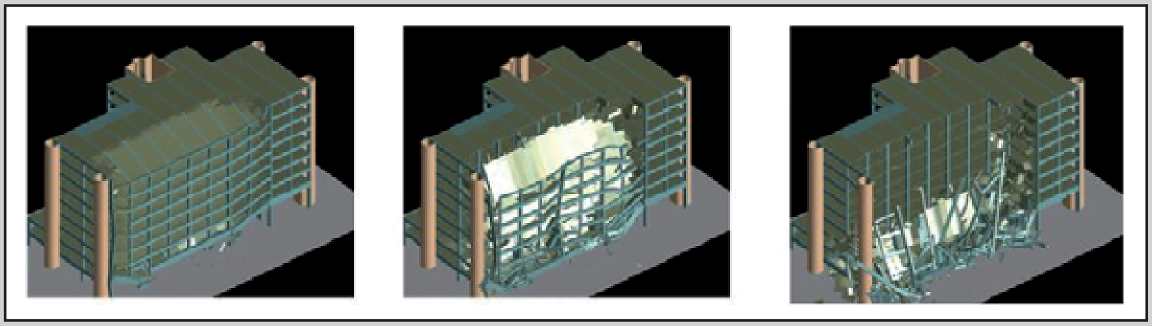
All structural dimensions, including the reinforcement area, location, stirrups, and concrete cover can be taken into account in the simulation. Details about the building shape, geometry, loadings, and structural details are required, however, missing data can be assumed with reasonable values.

ASI modeled the A.P. Murrah Building, first to verify Extreme Loading software and second, to study the effects of a structure under a series of blast loading scenarios, demonstrating the value of the technology. Simulating a blast similar to the actual explosion, Extreme Loading calculated the effects according to the building's structural dimensions and reinforcements, friction parameters, load distribution, and nonstructural components. Extreme Loading's collapse simulation was similar to what was observed in the actual case in both progression and completion.

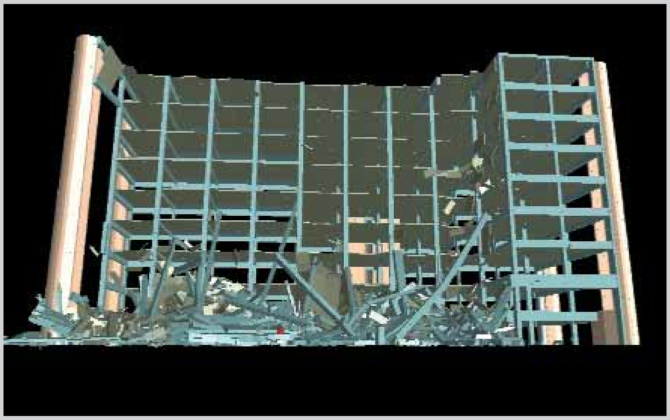


Model of the AP Murrah Federal Building Blast

In the minutes leading up to the tragic event, a truck loaded with the equivalent of 4000 pounds of explosives was located at the curb near the center of the 9-story reinforced concrete building. Within 5 seconds of detonation, the building lay in ruins, after having collapsed clear up to the roof. The explosion took out a supporting column, which was enough to cause the subsequent failure of a main girder and the progressive collapse of the building above this support. Experts agree that the transfer girder at the third floor level is believed to be responsible for the catastrophic collapse of the building. The total collapse process lasted approximately 4.5 seconds.



The above sequence is the latest simulation of the Murrah building collapse that only ASI can produce. When compared to the actual destruction caused on that tragic day, this simulation has opened a whole new chapter in the industry of vulnerability assessment. As one surviving family member commented when shown these simulations, “the lives of loved ones were not lost in vain if this technology can be used to save others.”



Collapsed shot of the Murrah Building

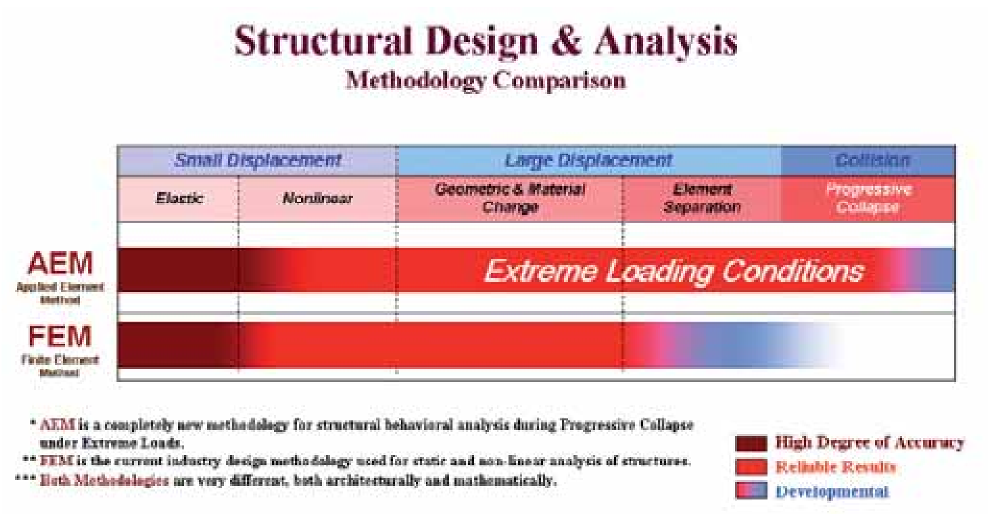
Analyzing a series of bomb locations illustrates the power of ASI's Extreme Loading technology and its applicability to the vulnerability assessment process. First, ASI moved the bomb was moved 65 feet east, to the corner of the building. With the bomb in this location, progressive collapse occurred, although the overall destruction was somewhat limited to the end bay. When the bomb was moved to a point 25 feet across the street from the original location, a considerable reduction of the blast pressure and its effect on the structure occurred. However, floor elements failed to resist the significant uplift pressures.

Finally, the original explosion was duplicated after doubling the steel reinforcing bars in the main concrete girder. With the main girder intact and the columns above supported, the primary building structure sustained the blast. Again the floor elements failed, demonstrating the importance of resisting the uplift pressures. From this type of engineering analysis and real-time visualization, ASI is able to identify structural, architectural and building envelope improvements for a more secure working environment.

“A thorough understanding of a structure’s behavior, especially under extreme loading, is paramount for making the decisions necessary to provide a structurally safe working environment and to balance the cost to build, retrofit or secure. This new process of informed decision making can lead to life saving economic options and secure facilities.”
– Edward di Girolamo, ASI CEO

FEM v AEM – No Contest

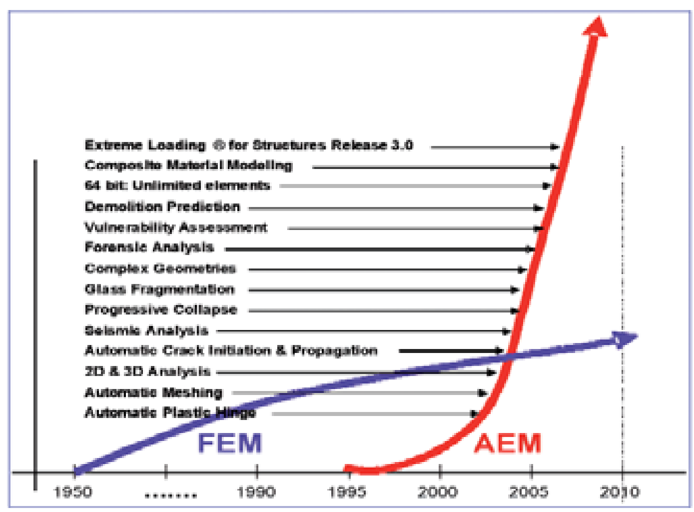
As was noted previously, until now design engineers have been limited to analyzing structures using an approach termed the "Finite Element Method", or FEM, a theory that is based on bodies that do not physically separate. In very simple terms, an FEM model bends but does not break or deforms but does not separate. Because the breaking apart of materials is a significant phenomena occurring in nature, when applied to building structures, the damage resulting from a partial or full collapse is not apparent with the finite element method.



ASI's Applied Element Method", or AEM, has been completed offering the advantages found in FEM in addition to the separation of bodies. It has the unique ability to determine not only when elements separate, but how they interact within their environment. This new AEM technology provides a first-hand opportunity for a more comprehensive understanding of the scenarios that cause buildings to collapse, and further opens the way to a better approach to diminishing the effects of these tragic events, thereby saving lives.

Unlike FEM, where designers are burdened with determining points of contact and the location of interface elements at predetermined failure locations, AEM based technologies simplify the inputs for crack initiation, point of contact, and load and object configurations when mobile complex geometries impact a stationary structure. ASI has also developed the capability to quickly model or import stationary complex geometries like stadiums, bridges, towers and other structures for detailed evaluation.

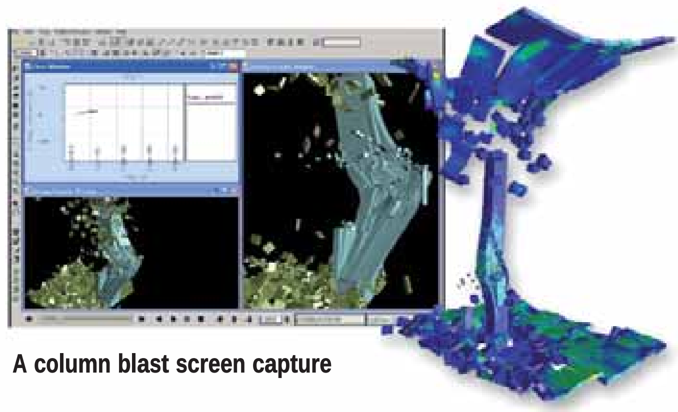
The progressive collapse of the Murrah building, the Twin Towers and others that are a result of man-made or natural disasters, has changed the way buildings are being designed and assessed. AEM technology was built specifically to address progressive collapse scenarios and assist structural engineers with performance based design options. Because of this, ASI technologies can quickly model a building design and test it for progressive collapse under extreme loads. If there are no alternate paths for the structure's weight to be supported, the building may experience vertical and horizontal collapse. ASI provides the tools and services necessary to make design changes before the structure is built or methods to retrofit buildings and mitigate risk.



It's Better Because…

Simulation programs currently use the Finite Element Method (FEM) to conduct structural collapse analysis. FEM, however, is not effective when the locations of cracks are unknown, when cracks are wide, or when elements actually separate. FEM may be able to model events up until the moment of collapse, but it cannot be used to analyze the separate stages and progression of the collapse.

ASI uses its new analytic approach – the Applied Element Method (AEM) – to accurately and speedily calculate and model progressive nonlinear behavior.



A column blast screen capture

What It Does

Variables	Collapse Behavior	Scenario Assessment
Structure type (building, bridge, tower other complex geometries)	Loading	Will the building collapse?
Structure material (reinforced concrete, steel)	crack initiation, crack propagation	How will it collapse?
Blast type (accident, bomb, impact)	element separation, element collision	What will be the duration?
Blast location (interior, perimeter, aerial)	progressive collapse	What happens to nearby buildings?
Blast magnitude	collision with adjacent structures	What is the effected perimeter?
Material selection	selection of required glazing and other materials	What is the level of perimeter protection measures?

Additional Benefits

- Ability to break out elements
- Ground breaking visualization
- Unlimited scenario options
- Much more rapid scenario generation saving time and money

ASI has also developed a one of a kind capability to determine the behavior of glass under extreme loads like blast, high winds and projectiles. Guarding against glass fragmentation during an extreme event is a critical element in preventing causalities. AEM technology records the velocity of glass fragments which helps building owners develop designs which will minimize casualties. This capability has and can be used to evaluate the types of glass used in construction projects and to make change recommendations to meet specified threats.

By combining an accurate pressure wave with glass and structural behavior, ASI provides for a comprehensive understanding of risks and opens the door to the possibility of extended perimeters as yet another safeguard for personnel and property.

The technology includes post-processor viewers to interpret AEM analysis, allowing users the option to see both 2-dimensional and 3-dimensional graphical representations.

The inherent advantages of 2D analysis include shorter run times and an increased number of elements.

It also offers extensive options, including color definition, navigation, contour, stress and displacement chart options, and velocity trails of elements - all add value to the structural assessment.

PART TWO

Vulnerability and Risk Assessment – The Better Approach

CASE STUDY
RISK ASSESSMENT

Frank Ehrman, Security Consultant with Security Management Consulting

"On of our clients is putting up a new building codenamed 'Fairwinds Project' so that it remains anonymous. It is a high rise skyscraper – a multi-use new building and we were brought in when the design was pretty much locked in. We were asked to do a security assessment and we said that the first thing that had to be done was to get the eight stories of parking out from under the building and, if the data center was so critical, to move it out into the country.

"Of course, they were dumbfounded and said that could not be done. So we started talking about what could be done. Fortunately the risk of being blown up or attacked is still pretty small but these are forward thinking owners and they wanted to know about the effects of bomb blasts and bomb mitigation. That is when we got in touch with ASI and we immediately saw the value in their software.

"Back in the dark ages – during my 26 years as a mechanical engineer, we used fixed element analysis and there was always a problem doing studies like this because of its inflexibility. When you had a very complex structure FEM became almost unusable. It also required a great deal of computer talent because you had to constantly tweak it to get it right.

"I am not seeing this with AEM – it accurately models a structure much more quickly than other models and you don't need a main frame computer for it – it can run on what is considered a normal PC today.

"I am really amazed at the software. It is a very good tool. For new construction, it can tell you what can be done economically to avoid progressive collapse and how to be able to evacuate the people from a building to save lives. For existing structures it can show a packet of things you might be able to do to retrofit.

"We have also used the software for glass analysis to see how the building windows would be impacted by 90mph winds. By adding laminated glass the windows would not fail and could, in fact, withstand winds of up to 120mph. We were then able to look at the likelihood of the building being subjected to these kinds of winds and the impact on the cost of replacing the glass on some of the floors. It was decided that the risk was small and there was no cost advantage –which is all part of risk assessment. However, this tool allowed us to make an informed judgment because it provided us with much more knowledge about the behavior of the building under various scenarios.

"As far as we are concerned it is an excellent tool and we will use it. It is only one tool we use in risk analysis but the more data you have the more educated your guess will be.

"It has many advantages. For an existing structure you need to deal with the likelihood of an event occurring and if so, whether you should take this data and run with it and turn the building into a hardened facility.

"In the early stages of a project, this analysis could even change the client's thinking about where he wants to put the building. If it is a high visibility, high risk structure it could save a lot of money by building it elsewhere.

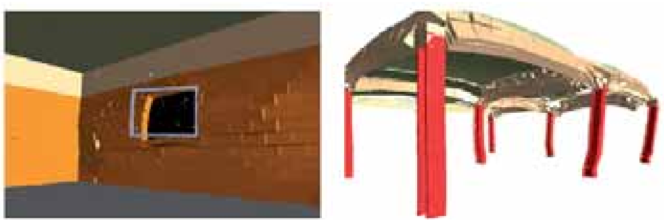
"More and more owners are now focusing on threats to their buildings because they know they have to do something about it but it is usually too late in the process. Once you have got the design, the hole dug and cement being poured it could almost be too late to do anything about it – you are not designing any more you are redesigning.

"Risk assessment and this sort of analysis has to be done as early as possible in the design stage when the architect it still working in cyberspace drawing on a computer. That is the time when the ASI software could be invaluable."

Applied Element simulations come to life and present a near virtual reality movie of the structure's behavior. This is what sets apart an ASI vulnerability assessment from traditional methods and gives building owners and decision-makers clearer perspectives of what they need to know to protect their facility.

The traditional threat assessment, asset rating and vulnerability assessment generate a numerical rating, but ASI's structural assessment generates its own color coded rating based on the specified scenarios. The two are overlaid and a combined Risk Assessment reveals a more accurate picture to the building owner and other decision makers. ASI has further developed several resolution matrices to assist owners in interpreting risk assessment results and making economically sound decisions regarding architectural, structural, building envelope and procedural changes to improve security and the safety of the building and its occupants.

While the threat assessment, asset ratings and vulnerability assessment are being developed and evaluated, the structural assessment is linked through common objectives and vulnerabilities. The assessment team made up of building owners and project principles like the architect, engineer and security, through the assistance of ASI, identifies key locations and structural components for evaluation.



Blast of the parking garage

From there, the structure is modeled and the specified scenarios are simulated to determine the extent of the damage, the structural impact, and the loss of life and services. ASI's assessment process focuses primarily on the structure's vulnerabilities for architectural, structural and building envelope. Once a structure is compromised, all other safety measures may be put at risk. This improved procedure as part of the Risk Mitigation planning process makes a significant difference in the decisions needed to protect both personnel and property.

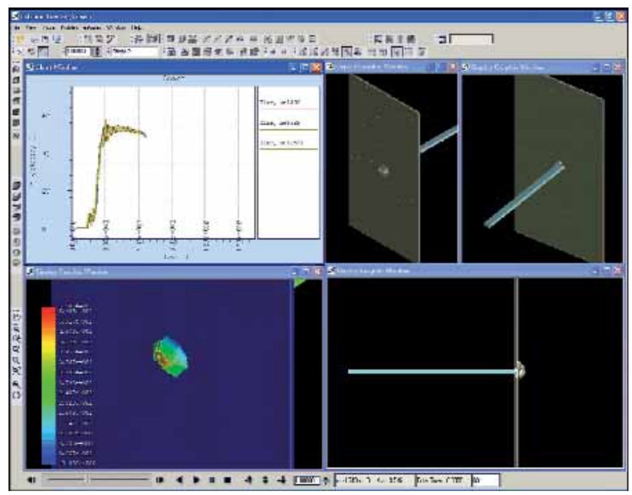
Analysis is based on client requirements but may also include progressive collapse, seismic, demolition, forensics and other structural engineering analyses that can contribute to a structure's vulnerability as well. Recommendations are coupled with security considerations, interior and exterior threat zone determination, safety egress development, risk mitigation, and protective design measure planning.

These time saving technologies are capable of assessing different security scenarios in a considerably shorter processing period than the leading tools in the field; days as opposed to weeks. This gives ASI analysts the singular capability to determine and recommend performance-based design solutions in absolutely minimum time.

The traditional vulnerability and risk assessment model:

Risk Assessment & Mitigation

The advantages of the new assessment method is that it can result in beneficial design and policy changes in a number of areas such as the structure, exterior glazing, perimeters, traffic restrictions, emergency egress policies and procedures, relocation of critical assets, refined extreme weather measures and so on.



ELS analysis of the glass penetration example

PART THREE
Solutions That You Can See Will Work

In this fast-paced dynamic world new challenges present themselves everyday, and structural engineers must constantly adapt and evolve to meet them. Whether the goal is to cut costs, provide security against terrorism and natural disasters, retrofit existing structures or demolish buildings, the tools used by engineers must be as dynamic as the projects with which they are dealing.

ASI's Applied Element Method coupled with Extreme Loading for Structures is the world's first tool to accurately analyze and simulate 'real-time' structural responses from the point of loading through cracking, element separation, and total collapse. Powered by the AEM technology, it enables analysis of progressive collapse under a variety of conditions. Variables such as dynamic, seismic, blast, and demolition scenarios as well as traditional static analysis are available for both concrete and steel structures.

Extreme Loading for Structures (ELS) caters to numerous structural engineering disciplines including:

- Reinforced Concrete and Structural Steel Analysis
- Progressive Collapse Analysis
- Seismic Analysis
- Blast Analysis
- Slab Analysis
- Foundation Analysis

It can also be applied to almost any structure from high rise buildings to historical structures, bridges, stadiums, arenas and even elevated water tanks.

What It Can Do For You
BLAST ANALYSIS

ASI's blast modeling technology is superior to most, if not all, simulation tools used or based on Finite Element Method (FEM) technologies. Blast is an extreme loading condition that is often employed to produce a progressive collapse scenario. ASI can model structures and run more blast threat scenarios in an allotted time period than any other leading software tool. Using this technology, we can more easily model the structure in record time and run multiple blast scenarios to determine structural vulnerabilities and threat envelopes.

This rapid prototyping capability allows for quicker decision making where building perimeters, barricades, reinforcements, and other blast mitigation or security procedures to protect people and property are of primary concern. ASI can also determine debris fields and predict casualty and collateral damage areas. Extreme Loading identifies a structure's vulnerabilities by visually simulating and analyzing the effects to, and responses of, a structure suffering explosions of varying strengths. ELS–BLAST enables the simulation of a wide variety of scenarios to deliver real-time results. Assessing a structure's weaknesses is performed via scientific analysis allowing for the maximum protection of the structure and a minimization of the potential for casualties. ELS-BLAST affords the means to:

- Determine strategies to mitigate loss
- Strengthen weaknesses
- Refine enhancements
- Minimize access to critical areas
- Determine effects on neighboring structures

TERRORIST THREATS

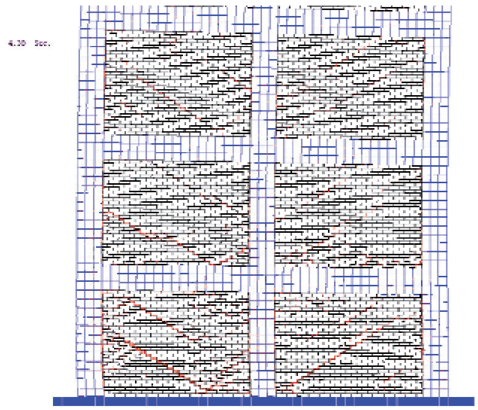
Before April 1995, earthquakes were usually cited as the primary cause of building collapse. But with the bombing of the Murrah Federal Building in Oklahoma City – and the even more devastating attacks on the World Trade Center and Pentagon in 2001 – terrorism has raised the stakes for security experts and structural engineers.

New buildings have to be designed to withstand blasts – among the most powerful of extreme loads – and existing buildings need to be analyzed to see how vulnerable they are and what can be done to mitigate an attack.

Even small explosives can inflict sizeable damage to a structure if they are set in the right location. Design hazards must be identified and mitigated to successfully suppress devastation before a blast occurs.

Through the use of Extreme Loading software security experts can identify the vulnerabilities in an existing structure or in the plans for a new building, allowing the critical structural elements to be reinforced so as to prevent building collapse.

SEISMIC



A seismic analysis screen.

EARTHQUAKE ENGINEERING AND ANALYSIS

ASI has developed an engineering capability to conduct earthquake analysis. This technology has a predictive capability closer to reality than most, if not all, advanced engineering software tools. ASI works with clients and structural engineers to determine the design criteria for a project and can complete a full earthquake design assessment to illustrate how the structure, planned or existing, will behave under multiple seismic conditions. An earthquake assessment will help identify opportunities for risk mitigation by architects and engineers of record.

ELS-Seismic delivers the ability to produce a wide variety of structural responses to seismic loading, such as:

- Seismic effects on a structure
- Effects on neighboring structures in the event of a collapse
- Seismic effects on a bridge

DEMOLITION ANALYSIS

The demolition industry often works with an engineer of record who is unfamiliar with demolition practices. To allay any concerns, ASI provides a unique service in two areas; proposal development and demolition analysis. AEM technology and rapid prototyping capability allow a structural model to be built in record time and then conduct a demolition of the model according to anticipated or proposed plans.

ASI analyzes and simulates the demolition of concrete, steel and masonry structures complete with their walls, glass facades and other structural and cladding elements, all in a 3D environment. It incorporates rebar detailing, concrete strength, composite sections, prestressed beams and slabs, and other advanced structural details that impact the demolition to predict the outcome of the deconstruction plan.

DEMOLITION IN THE 21ST CENTURY

"Now, our clients, the architects, engineers, specification developers, and purchasing managers of the firms we work for are 'demanding' institutional quality control programs. They are comparing your quality assurance efforts with those of your competition. Our customers are becoming more and more concerned with guaranteeing a 'safe' job than simply relying on the low bid.

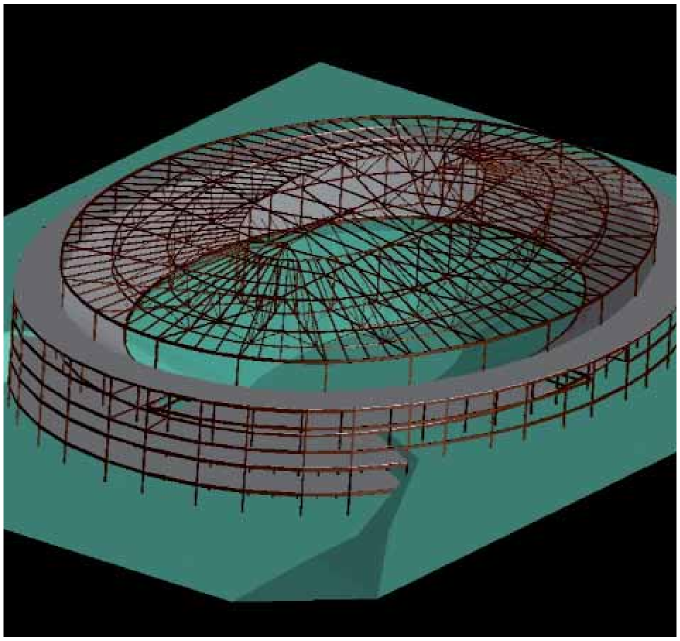
"This quality control effort means that our clients want to know exactly how we intend to perform the work we bid on. If an electrical contractor has to tell the client how much wire he intends to use and a mechanical contractor how much pipe, why can't a demolition contractor be made to explain his 'means and methods'?

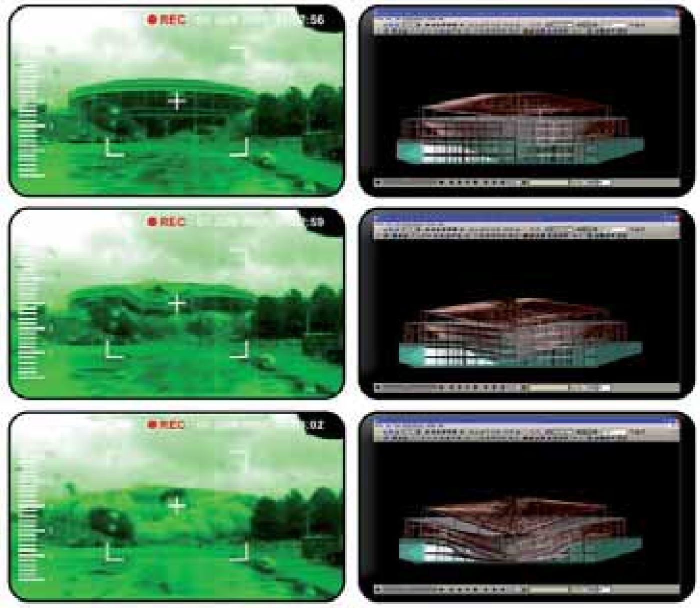
"The era of quality assurance is upon us. It is essential for the Demolition Industry and its Association to develop programs that define exactly what we do and how we intend to deliver the best service possible to our customers.

Source: Demolition Magazine March/April 2007.

The demolition industry often works with an engineer of record that is unfamiliar with demolition practices. To allay their concerns, ASI provides a unique service in two areas; proposal development and demolition planning and analysis. AEM technology and rapid prototyping capability allows a structural model to be built in record time and conduct a demolition of the model according to anticipated or proposed plans.

ASI analyzes and simulates the demolition of concrete, steel and masonry structures complete with their walls, glass facades and other structural and cladding elements, all in a 3D environment. It incorporates rebar detailing, concrete strength, composite sections, prestressed beams and slabs, and other advanced structural details that impact the demolition to predict the outcome of the deconstruction plan.





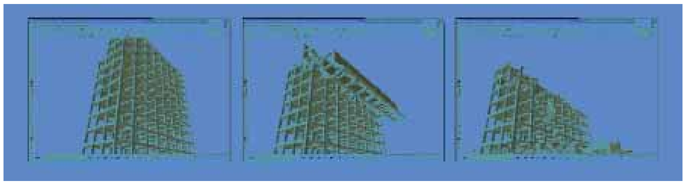
On June 3rd, ASI opened a new era in engineering simulation with a dramatic demonstration of its breakthrough technology. In North Carolina, the Charlotte, Coliseum was demolished in a spectacular 13-second implosion, leaving only a pile of metal, concrete, and rubble to mark the spot where this celebrated structure once stood. What singled out this event from all other implosions, however, was the historic significance attached to its deconstruction. Because of the utilization of ASI's revolutionary technology, the demolition plan was fully simulated beforehand with the results being demonstrated to the developer, general and demolition contractors, and public relations media prior to the implosion.

When asked about the drive behind the creation of this new technology, ASI Chief Executive Officer Edward di Girolamo stated, *"Our goal began almost 12 years ago with the desire to create a new technology that would be capable of completely redefining how buildings are designed, analyzed, constructed, protected and demolished.*

"By reinventing the approach currently used (one that was developed in the 1950's), we have created the capability to predict and visualize a structure's behavior in a manner found nowhere else.

"This demonstration is the first time an actual full motion, virtual reality, engineering simulation has been done for a demolition beforehand. All that most spectators saw and heard was a series of explosions, a dust cloud raised from the collapsing structure, and the disappearance of the roof line behind the cloud. What ASI was able to demonstrate was the progressive collapse of the coliseum from start to finish and from every desired angle – both inside and outside of the building,." said di Girolamo.

Today ASI applies its technology in construction design and analysis, in vulnerability assessment and risk mitigation planning, in forensics, and in deconstruction. The event in Charlotte not only demonstrates ASI's plans to change the way engineers build, protect and demolish structures, it signals the onset of a new era in simulating the known built world.



Strategies and Solutions

This technology has applicability to many fields or disciplines including:

- Vulnerability Assessment and Risk Mitigation
- Demolition and Deconstruction
- Insurance Underwriting
- Blast Analysis
- Glass Fragmentation
- Product Development
- Performance Based Design and Analysis
- Structural Engineering and Research and Development

End Users include

- Government/defense agencies and research laboratories
- Other security companies and consultants
- Building Owners and Property Managers
- Engineering companies
- General contractors
- Designers and Architects
- Insurance companies
- Demolition companies
- University Engineering departments

Visualization – how it works, what it does, what it can do for you

- Rapid structural modeling and scenario simulation
- ASI simulations approach virtual reality
- Show multiple perspectives
- Plan anticipated footprint of collapsed structure
- Conduct deconstruction stress analysis
- Graphics generated in multiple formats
- Performance based design recommendations
- New decision making matrix

This gives the engineer of record or building owner a better feel of the demolition outcome–seeing is believing. ASI provides services for analyzing, simulating and visualizing implosion scenarios. The simulations help communicate the implosion strategies to stakeholders, including insurance companies, and project owners during the bidding process. It also models implosion plans and scenarios, and tests structural details affecting the structure's behavior during demolition. Once the demolition plan is determined, an analysis on the actual blast sequence can be run to determine the expected outcome. ASI technology can also address vibration or seismic activity related to the blast and building collapse with advanced engineering analysis giving the entire project a measure of realism found nowhere else.

Demolition contractors can use this to test their own demolition plans and then to demonstrate to clients exactly what will happen during deconstruction. They can also use it to secure new bids by creating a visual portfolio simulating previous projects.

PROGRESSIVE COLLAPSE

ASI is an industry leader in assessing progressive collapse. Its visualization of structural behavior sets its product apart from all the rest, because AEM technology was developed from the bottom up with the intent to solve progressive collapse. Current FEM-based simulations appear as melting plastic models during failure without separation of elements, whereas AEM-based simulation shows the separation of members impacting other structural components during collapse. ASI technologies take the design process one step further. The engineer of record can easily modify designs prior to construction after identifying structural components that are most vulnerable. With this additional capability, design adjustments and security protection measures can be implemented in the most cost-effective manner.

GOVERNMENT/DEFENSE

The tragic events of 9/11, Hurricane Katrina, and the Oklahoma City bombing in 1995 raised significant issues relevant to structural behavior when exposed to extreme loads. The ability to accurately simulate such catastrophic events before they occur enables a municipality to better prepare for numerous contingencies. Applied Science International (ASI) delivers the only technology available to analyze the realistic progressive collapse of a structure.

Extreme Loading Technology helps to protect vital structures against malicious attacks through the simulation of the effects of blast, impact, and progressive collapse on structures and their surroundings. Extreme Loading for Structures can ensure the safety and security of civilian and government structures alike through its power to:

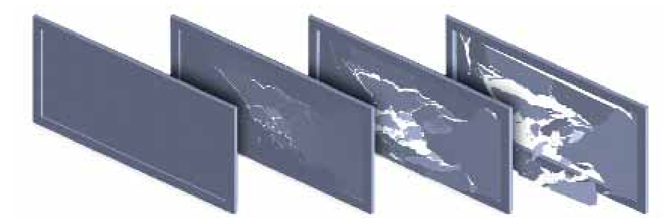
• Determine strategies to mitigate loss
• Strengthen weaknesses
• Refine enhancements
• Minimize access to critical areas
• Determine effects on neighboring structures

HURRICANES AND HIGH WINDS

High winds generated by hurricanes can result in wind-born missiles impacting on glass windows and on walls which are non-structural components. ASI can simulate accurately the effects of wind-born missile impact. The simulations consider the type of glass windows (laminated, or single layer, tempered and shear strengthened windows), missile shape, speed and mass. The output contains the fragmentation speed, if any, the estimated hole dimensions and so on. This type of analysis leads decision makers to select glazing materials for the anticipated hazards related to airborne objects and projectile blown from adjacent structures (e.g., roofing material and other objects) by gale force winds.

ASI assesses structural safety due to hurricanes. Safety considerations includes the structural behavior due to high impact resulting from falling objects from adjacent structures (even collapse) and the structural behavior due to pressure resulting from high wind speeds. All types of structural systems and materials can be evaluated to determine structural integrity under these extreme loading conditions.

Glass Analysis under Extreme Loads



ASI has the only software in the world that can easily model a glass panel, multilayered panels and connections given its material properties, and run simulations to determine glass behavior under extreme loads. This type of analysis contributes significantly to material selection, casualty assessment, wind blown hazard analysis, vulnerability assessment, and risk assessment of construction projects. The results of glass analysis will assist building owners, property management companies and their security consultants in identifying safety issues and formulating quick response procedures, making building design changes and in determining the need for perimeter barricades, material selections and other security measures.

Extreme Loading introduces the first complete simulation technology for the analysis of blast effects on glass panes, including the power to predict the post-failure flight paths of the dispersed fragments.

In these instances, Extreme Loading's technology has the ability to:
• Determine strategies to mitigate loss
• Strengthen weaknesses
• Refine enhancements
• Minimize casualties/damage
• Determine effects on neighboring structures

Forensic Engineering and Expert Witness

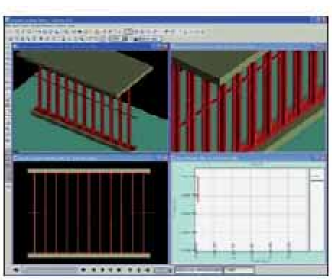
ASI has experience with forensic engineering and in providing the assessment for expert witness testimony. Forensic engineering involves prediction of a threatened outcome or post-event determination of events. ASI has the capability to accurately model the scenario and determine variations as the investigation or trial continues and the variables or facts related to the structure become known. Again, the speed of computing and labor saving technologies unique to ASI makes us the preferred choice.

Insurance Underwriting Evaluation

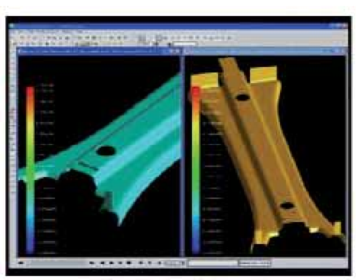
ASI provides behavior analysis of existing buildings and future construction for insurance underwriting purposes. ASI will do a complete structural analysis of buildings for natural or man made extreme loading conditions (e.g., earthquake, hurricane winds with debris, blast, etc.) for both interior spaces and external perimeters. This analysis will provide insurance underwriters with structural information for ratings on safety and vulnerability, and security companies with more detailed information for use in making recommendations for risk mitigation; all of which ultimately affect the pricing of building and liability insurance policies.

Research & Development: Model, Simulate & Live-Blast Test

ASI has the capability to model and simulate structures and materials prior to live blast testing. ASI has partnered with major universities and government agencies to conduct research and test new materials and product designs for mitigation of damage resulting from blast. Because our materials library and structural behavior modeling capability is highly adaptable to new geometries and physical properties, product behavior can be simulated long before resources are spent to conduct live blast testing or making manufacturing commitments.



TSN SigmaStud®



TSN BuckleBridge™

Specialty Services

- Historical Sites: ASI has participated in several historical site activities to determine the structural integrity of structures, monuments, statues, and other items with unique geometries and/or material properties.
- Building Owner & Property Management Consultation: ASI provides building owners and commercial property management companies with the same vulnerability assessment capabilities offered above so that properties can be evaluated for security and safety under threat conditions and other extreme loading events
- Software Customization: ASI has the capability to customize its software tools to assist with any special project, ranging from emergency first responder tools for determining structural integrity after an attack to blast testing of new materials or geometries, to determining the effects of meteorites on lunar outposts and so on. With an accurate depiction of the item's material behavior, ASI's technology can model it and simulate it closer to reality than any other product, in a shorter period of time, and on a personal computer.
- Proposal Generation: If a firm or activity needs to render the anticipated construction design or demolition of the same as part of a proposal to a government entity or any other Request for Proposals, ASI can assist by modeling the building beforehand. This type of technology will eventually become a standard business practice, but today it provides the decided edge in communicating capability and planning capability.
- Educational Seminars: ASI seeks opportunities to partner with Universities that have structural and civil engineering curriculum, and other training companies associated with demolition, forensics, structural engineering, training, insurance, security, property management and vulnerability assessment. Our combined objective would be to augment your presentation materials with realistic and accurate simulations. ASI is also able to facilitate training on the Threat and Risk Assessment methods described in this Special Report to Cities, Municipalities and property owners as needed to ensure a safer working environment.
- Educational Material Generation: ASI has the graphics and engineering capability to quickly model structures for analysis and/or training. It is one thing to view a static diagram of a dynamic scenario, it is quite another to view that same scenario in full motion video.

Summary

Because it was developed from the start to address progressive collapse, this revolutionary technology gives structural engineers the means to quickly evaluate design options and improve structural integrity.

Analyzing a series of threat scenarios illustrates the power of ASI's technology and its relevance to the vulnerability assessment process.

ASI has also developed a totally new method of determining the behavior of glass when subjected to blast, high winds, and projectiles. Because guarding against glass fragmentation during a catastrophic event is a critical element in determining perimeters, selecting materials and thereby preventing causalities becomes of paramount importance.

These assessments provide the big picture allowing more informed architectural decisions such as relocating a public meeting place or a server room to a more secure location within the building.

With these new vulnerability assessments of critical infrastructure and 3-D models of building egress plans, first responders, police and firemen can see and best plan how to act more safely and deliberately in response to unpredictable events.

ASI's technological achievements can also model and assess more complex geometries like stadiums, bridges, towers, and historic monuments.

"The 'what if' scenarios continue to take shape as ASI applies its technology in earthquake and hurricane prone areas enabling designers to accurately predict a building's performance during seismic activity, and its reaction to extreme winds and rising water tables.

"From pre-construction planning through the life-cycle of the structure, building and facility owners are part of an even greater community of concerned owners and citizens who are evaluating threats and vulnerabilities – especially where the structure is the first line of defense.

"Once you see it, you will have taken that first important step in making a difference - towards correcting or minimizing the risk and improving the structure's resiliency to attack or other disaster. We face many real threats today and we must all be prepared to meet them."