Blast Mitigation Effort

Lead: Arun Shukla, University of Rhode Island

Dynamic PhotoMechanics Laboratory

This research effort will focus on basic science issues that help develop novel materials and structures to mitigate blast effects

Research Thrust Areas:

Designing and understanding the response of novel heterogeneous materials, including particulate, layered and functionally graded materials subjected to extremely high strain rate blast loading conditions.

Designing and understanding the response of sandwich composite structures subjected to extremely high strain rate blast loading conditions at room and at high temperatures.

Studying deformation and progressive failure events of structural steels subjected to coupled high strain rates and high temperatures associated with blast/fire loadings.

Studying the response of structures that couple rigid body dynamics, material deformation and load transfer.

Blast Mitigation Effort (*Con'd*)

Lead: Arun Shukla, University of Rhode Island

Dynamic PhotoMechanics Laboratory

- Understanding structural response to separate and simultaneous blast and fragment impact.
- Understanding structural response to blast waves from internal explosions, particularly non-ideal explosions.
- Coatings for structural protection during blast.
- Self healing materials and smart protective structures.

The above mentioned research thrust areas, while they do not encompass the entire scope of mitigation, have been selected to provide a focus in the initial stages of research.

Novel Composite Materials & Structures for Blast Mitigation

Arun Shukla, University of Rhode Island

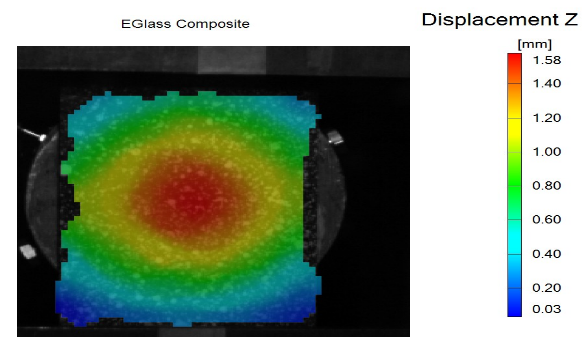
Dynamic PhotoMechanics Laboratory

Purpose/ Relevance: Conduct fundamental experiments to elucidate physical mechanisms responsible for damage in novel composite materials & structures subjected to extreme environments associated with blast & fragment loading, thus leading to new more efficient materials & structures.

Shock Tube

Innovation: Highly controlled experiments with real time measurements at extremely high loading rates to give full field load-deformation & damage information at material & structure level.

1st year outcome: Constitutive behavior of selected materials at very high strain rates and also at high temperatures. Incorporating the new DIC technique in initial experiments to investigate blast response of some selected materials and architectures.



Long-range impact: Design of new multi-functional materials with excellent blast mitigation capabilities & with ability to heal and overcome other hazards.

Digital Image Correlation

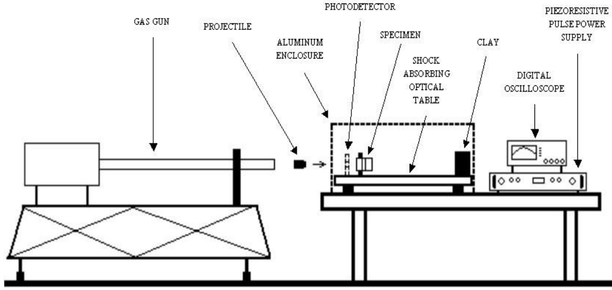
Shock Mitigation through Particulates

Carl-Ernst Rousseau - University of Rhode Island

Purpose and Relevance: Focus on understanding Stress Wave Scattering, and using it as a means of mitigating suddenly imposed stress conditions due to explosions or impact. Efficient diffusion of those waves can help with the development of advanced materials that have the merit of withstanding high loading rates.

Innovative Aspects: Stress weakening through the use of particulates is generally acknowledged, though the phenomenon is seldom studied and understanding of the physical phenomenon is in its infancy. Tracking of stresses as they travel through particulate materials will help identify reasons behind their behavior.

Year 1 Outcomes: Establish geometries that reduce severity of traveling wave & identify those that sustain stresses near their incoming levels. Intensive use of Lagrange stress gages will constitute a primary tracking mechanism.



Long range Impact: Development of materials based on particulates will find direct applications to infrastructure, transportation, and blast shielding, including sheltering of sensors.

Deformation and Progressive Failure of Structural Steel Subjected to Coupled Blast/Fire Loadings – Experiments & Modeling

Hamouda Ghonem & Otto Gregory - University of Rhode Island

Purpose and Relevance: An integrated multidisciplinary program to develop a fundamental understanding of the mechanics and mechanisms of deformation of structural steel subjected to blast/fire loadings. This approach will result in the development of a real-time numerical simulation platform to serve as a tool to predict progressive collapse of steel members in blast loaded structures.

Innovative Aspects: A collaborative effort that includes a novel and highly accurate Internal State Variable model, dynamic experimentation and large-scale simulation that aim at producing a computationally efficient predictive model suitable for large-scale structures and accurate enough to capture detailed behavior of steel members' inelasticity and instability associated with effects of explosion and fire.

Year 1 Outcomes: Large scale experimental program which will provide the kinematic, isotropic and relaxation response of structural steel as a function of blast deformation and thermal exposure parameters.

Long range Impact: Develop efficient real-time simulation platforms as a prediction tool to establish design requirements and survivability criteria for steel members in a structure subjected to blast & fire loadings.

Deformation and Progressive Failure of Structural Steel Subjected to Coupled Blast/Fire Loadings (cont)

Hamouda Ghonem & Otto Gregory URI

Develop economically viable techniques for of a new generation of structural steel with high deformation and creep resistance.

- Metrics: The viscous flow equations of structural steel will be generated using materials subjected to a set of measured shock waves energies coupled with & without thermal exposure. These equations, which currently do not exist, will be tested by comparing their outputs with the response of steels subjected to blast conditions. The reliability of a large scale progressive failure model, based on the developed viscous flow equations, will be examined using optimization techniques & comparisons with scaled steel structures subjected to blast.
- Importance in "filling gaps:" For many years, steel members will remain the key components in large structures designs. The first goal of the project is the generation of a model to predict failure events associated with blast shock waves. This failure mapping will be translated into a survivability (after events) criteria for future steel structure designs. The long term objective of this work is the development of a steel microstructure with high resistance to blast loadings. This type of steel has not been developed to date.

Structural Response to Non-ideal Explosions

JE Shepherd, California Institute of Technology

- Purpose/Relevance: Investigate fuel vapor cloud explosions inside yielding structures.

- Innovative Approach: Develop methods that are useful for analyzing potential explosive hazards or investigating accidental or deliberate non-ideal explosions inside a structure.
- Unique focus on non-ideal gas explosions (deflagration) inside weak structures.

- Year 1 Outcomes: Simple models and small-scale experiments.

- Long range Impact: Develop mitigation measures and improved structural design guidelines.

Optimal Design and Development of Advanced Materials

C. S. Yoo and Y. M. Gupta, WSU

Purpose: Advanced material design & development to mitigate explosive & high-velocity impacts.

Innovation: Integration of materials modeling & in-situ measurements at high stresses (1-30 GPa) & short time (ns-us) scales relevant to explosive detonations & fragment impact.

Year 1 Outcomes: Determine the load path under axisymmetric loading conditions and understand the spatial and temporal variation of compressive, shear, and tensile stresses on the target

Long range Impact: It is critical to design and develop shock-resistive advanced materials and to understand dynamic responses of the materials on or near strong explosive impacts

Compact Pulse Power Machine at WSU, to be used in our impact experiments

Optimal Design and Use of Advanced Structural Materials to Mitigate Explosive and Impact Threats

J. Baird and J. Myers, Missouri S&T

Purpose: Advanced material design & development to mitigate explosive & high-velocity impacts.

Innovation: Integration of materials modeling & in-situ measurements at high stresses (1-30 Gpa) & short time (ns-us) scales relevant to explosive detonations & fragment impact.

Year 1 Outcomes: Determine the suitability of hybrid materials in barrier/wall systems to provide enhanced blast and fragment resistance

Long range Impact: The design and development of materials that perform well under severe dynamic events, and the understanding of material dynamic response to explosive detonations and fragment impacts is critical to the next generation of blast-resistant structures

Charge setting

Test of column fixture – wrapped reinforced concrete

Shot; 30 lb TNT-equivalent