Nano-Particle Reinforced Composites for Critical Infrastructure Protection

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Project overview

This project investigate the use of the recent advancement in material, structure, and building technologies for the protection of critical infrastructures, which include governmental buildings, emergency response system (police station, fire house, hospital), oil and gas pipelines, power and communication transmission towers, etc., against terrorist threats, as well as natural disasters.

The new structural/building technologies developed from this research can be used to improve the survivability of these structures. The findings, recommendations, and tools derived can become a part of the decision support system for local, state, tribal and regional leaders and emergency responders for better preparedness.

The research takes the multi-pronged and integrated approach, simultaneously addressing four research areas: material research ; structural component research; structural system research; and decision support system research.

Project goal

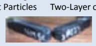
The goal of the current research project is to utilize the nanotechnology that is still being developed today, at the Basic Technology Research Level (TRL 1 & 2), and apply it to the nation's critical infrastructure protection at the Technology Development Level (TRL 5).

Structural component research

New nano-particle enhanced materials—carbon nanotube, glass and graphite platelets, and nano-clay, added to polymers and concrete—are investigated using both theoretical modeling and laboratory testing approaches

Particle dynamics (PD)

PM Accounting for Nearest Particles — PM Accounting For Two-Layer of Particles



Experiment

Fracture Pattern of a Polymeric Material (Nylon-6,6) Due To The Impact of a Rigid Indenter

Real Time Image of 2.5 wt. % Graphite Platelet/Vinylester Specimen Subjected to 120 psi Peak Pressure in Shock Tube

Molecular dynamics (MD)

SWCNT — MWCNT — Graphene

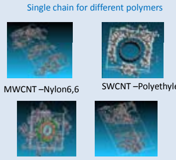
Graphite — MMT — POSS

Molecular structures for several Nanoreinforcements

Nylon 6,6 — Vinylester — Polyethylene

Polyurea — Polyurethane

Single chain for different polymers



MWCNT –Nylon6,6 — SWCNT –Polyethylene

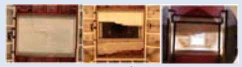
xGNP-Vinylester — GNP-Vinyleseter

Single chain for different polymers

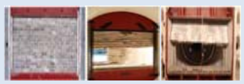
Structural component research

At this level innovative structural components and subsystems such as sandwich panels with foam infill, concrete masonry walls with elastomer coating and reinforced concrete columns are investigated.

(Experimental work) Retrofitted CMU walls under blast loading



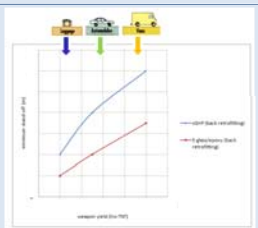
CMU wall retrofitted with polyurea



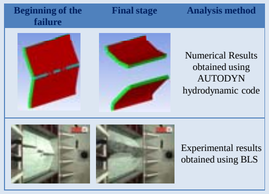
CMU wall retrofitted with XGnP reinforced polyurea

CMU wall retrofitted with POSS reinforced polyurea

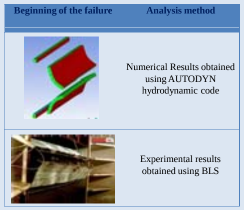
Minimum stand-off distance in case of CMUs retrofitted with either elastomeric or rigid retrofitting materials



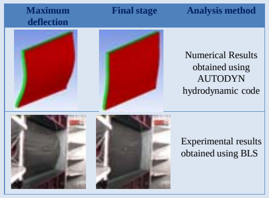
Deformation and failure shapes for the case of retrofitted concrete masonry unit (CMU) walls



CMU wall retrofitted with polyurea



CMU wall retrofitted with XGnP reinforced polyurea

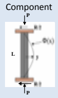


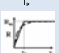
CMU wall retrofitted with POSS reinforced polyurea

Wall Number	Midpoint deflection at failure mm		maximum debris velocity m/s	
	experiment	simulation	experiment	simulation
Polyurea	91.4	102.61	3.86	4.44
Polyurea with xGnP	76.4	N.A	7.47	N.A
Polyurea with POSS	120.65	84.41	N.A	N.A

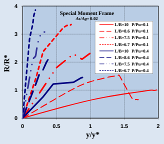
Strength and deformation capacity of components subject to blast and extreme lateral loading

Component





Resistance curve



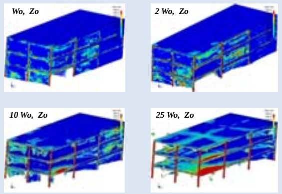
SAP2000v12 fiber model (fixed-pinned)

Fiber damage based normalized P-I curves

Structural system research

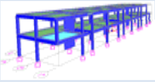
At this level of research, the potential benefits of using nano particle reinforced composites to enhance structural components in a full scale critical infrastructure system is examined.

Effective plastic strain distribution for eccentric side blast scenario



The response of a building to the removal of a column is analyzed using a three-dimensional finite element code. The building's resilience to an undesirable progressive failure is investigated and importance of shear walls on unintended slab and frame damage patterns observed.

Field experiment by controlled demolition

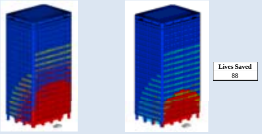


SAP2000 v12 finite element model

Decision support system research

At this level of research, the potential benefits of using nano particle reinforced structural components, in terms of improving life safety from a major blast event in a critical facility of significance to the State of Mississippi, is evaluated. Blast mitigation, casual assessment, and evacuation simulation are conducted for the State Government's Executive Building.

Simplified blast simulation to estimate extent of damage for evacuation scenarios



Unprotected wall — Nano-particle protected wall

3D model and typical floor plans used

E-sim model

1st floor layout

10th floor layout

Conclusion

Due to the innovative and high technology nature of the research, the current project covers a broad spectrum of TRL. For example, research accomplishments at material level may be classified as TRL 1 and 2, ***Basic Technology Research***. On the other hand, research accomplishments in developing blast protection barrier and emergency evacuation planning have reached TRL 6, ***Technology Demonstration***. By taking a multipronged approach we have achieved success at all levels, from basic material research, to component and system research, and to decision support systems research. However, due to the rather ambitious research plan and the relatively short project duration, firm connection between one level and the next has not been fully made. There are gaps to be bridged in order to provide a smooth flow of knowledge from the fundamental research level to the technology implementation level. This linkage is currently under investigation.

Publications

- Ten journal papers either published or submitted.
- Six conference papers.
- More than thirty presentations in national and international technical conference.
- One book chapter.

Future work

In the continuing research, the following additional material properties will be investigated for multihazard applications including fire, earthquake and hurricane: (1) thermal degradation/phase transformation of organic components in polymer nano composites during fire, (2) flammability and flowability of retrofitting materials, (3) heat transfer and associated heat induced fracture, and (4) aging retrofitting materials.

Acknowledgment

This project was funded through the Southeast Region Research Initiative program from the Department of Homeland Security, Science and Technology Directorate, Infrastructure and Geophysical Division.