Blast Resistance of Unreinforced Masonry (URM) Walls Retrofitted With Nano Reinforced Elastomeric Materials

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Outline

- Objectives
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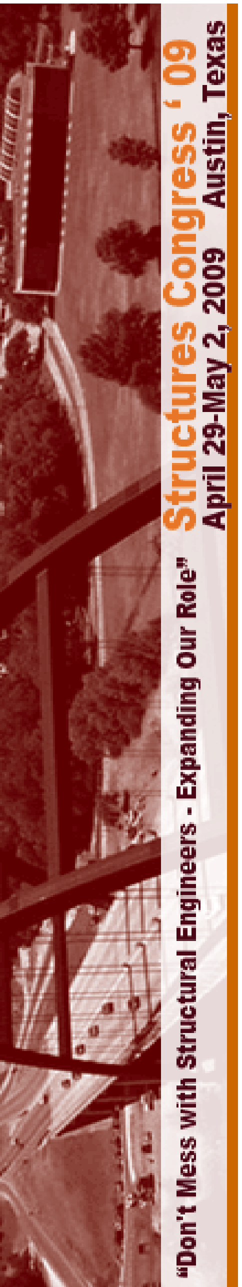


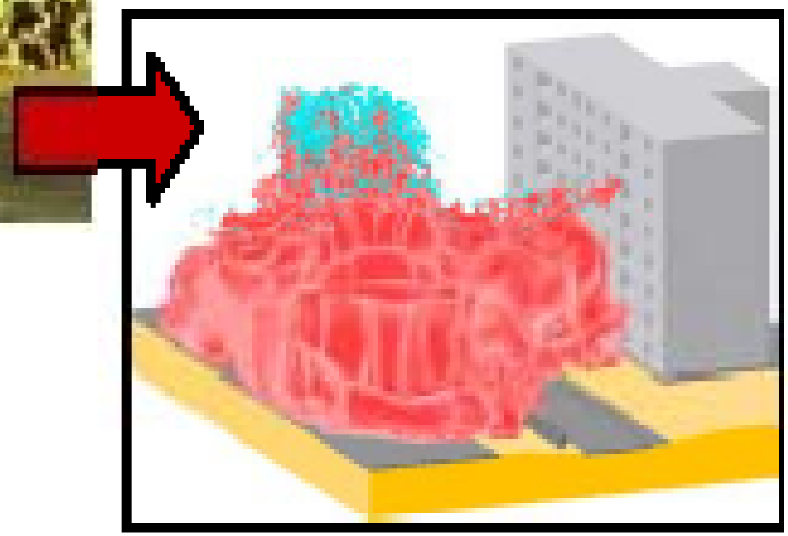
Objective

The main objective of this work is to investigate the viability of using Nano Particle Reinforced Elastomeric Materials (NPREM) to protect the masonry structures against blast loading experimentally and numerically.

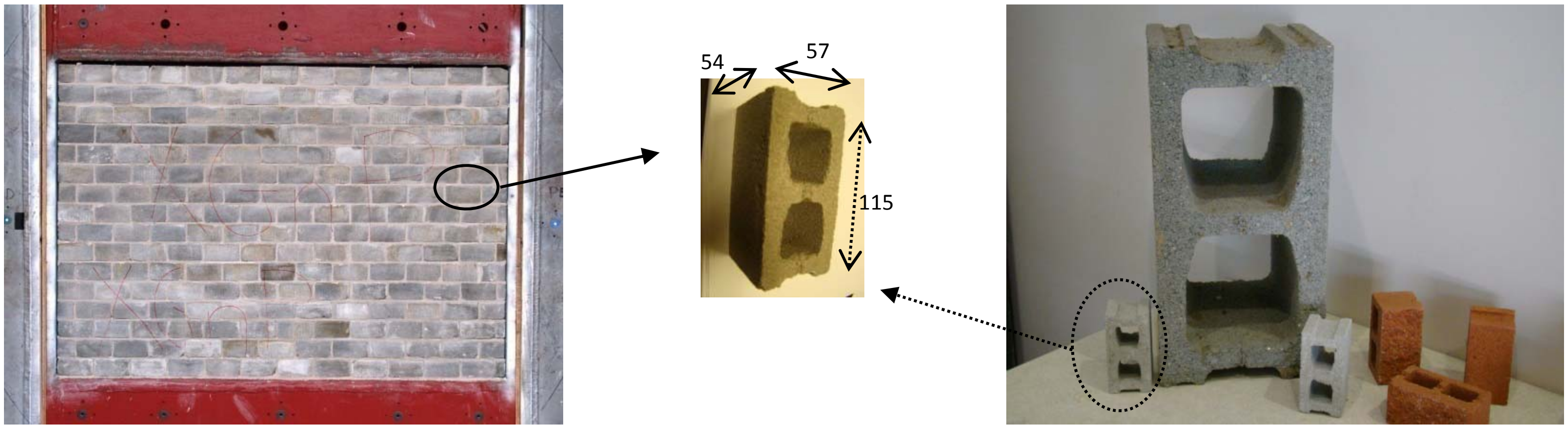
Problem Statement

Full Scale Blast Test

Numerical Simulation



Experimental Program



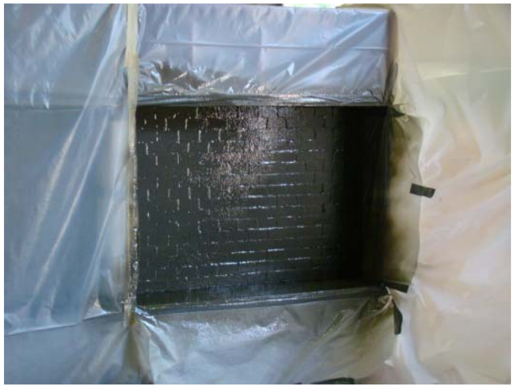
(a) (b) (c)

(a) Masonry wall dimensions (b) Concrete masonry unit brick (all dimensions in mm)
(c) comparison between full scale and scaled down dimensions of masonry unit

Three walls were tested at the US Army Engineer Research and Development Center (ERDC) using the blast simulator :

1. retrofitted with unreinforced polyurea
2. retrofitted with reinforced ployurea using exfoliated graphene nano platelets (XGnP)
3. retrofitted with reinforced ployurea using Polyhedral Oligomeric Silsesquioxane (POSS).

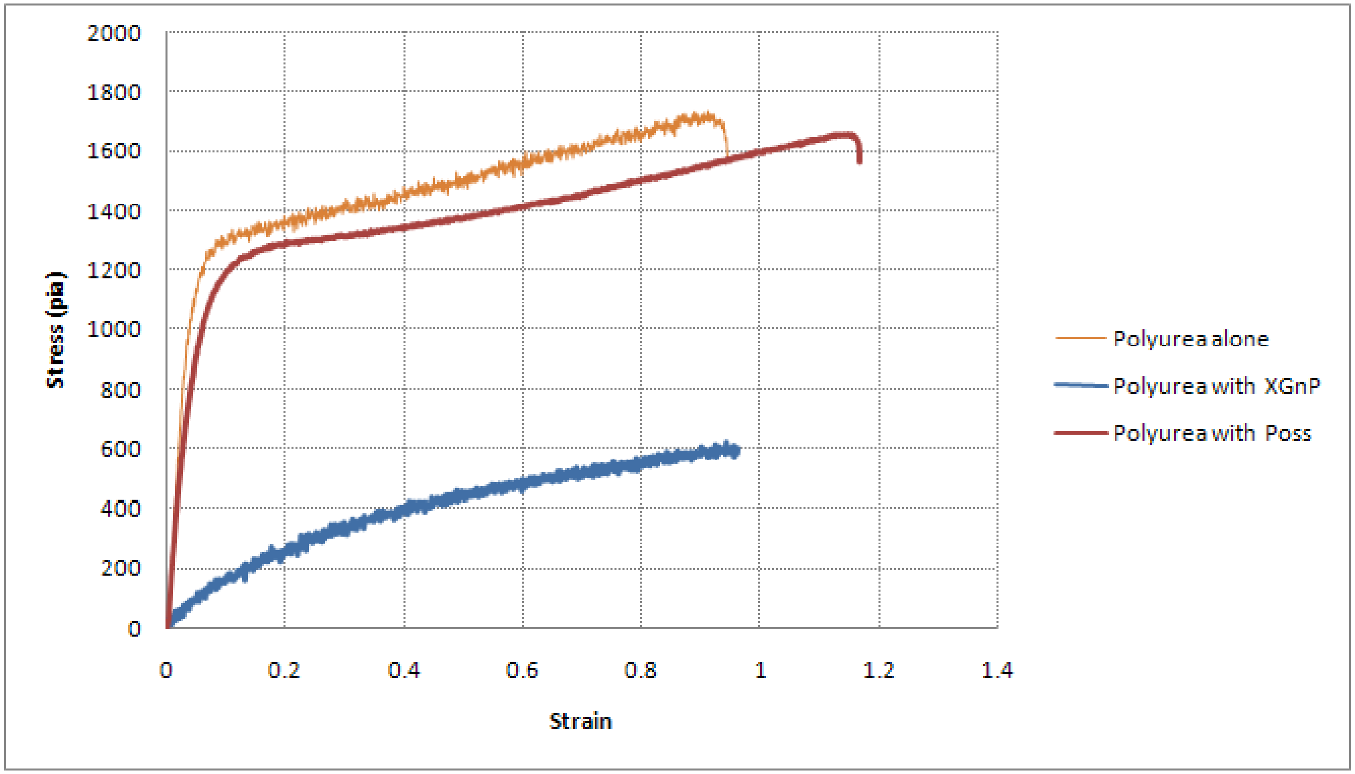
Retrofitting process



- Test Matrix of retrofit schemes

Wall Number	Retrofit Material
Wall #1	Polyurea alone
Wall #2	Polyurea reinforced with xGnP
Wall #3	Polyurea reinforced with POSS

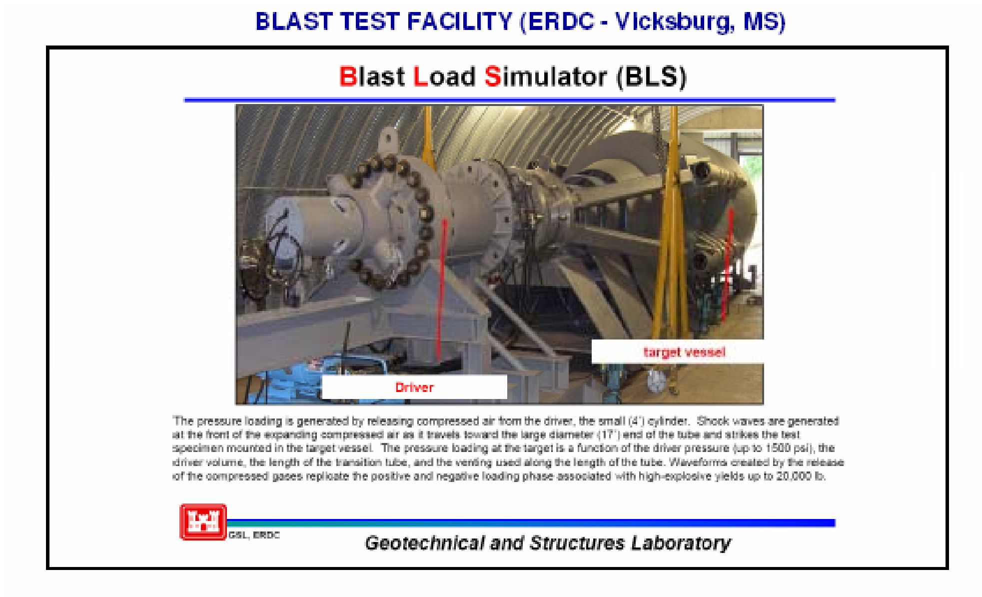
➢ TYPICAL STRESS-STRAIN RELATION FOR RETROFITTED MATERIALS UNDER TENSILE LOADING

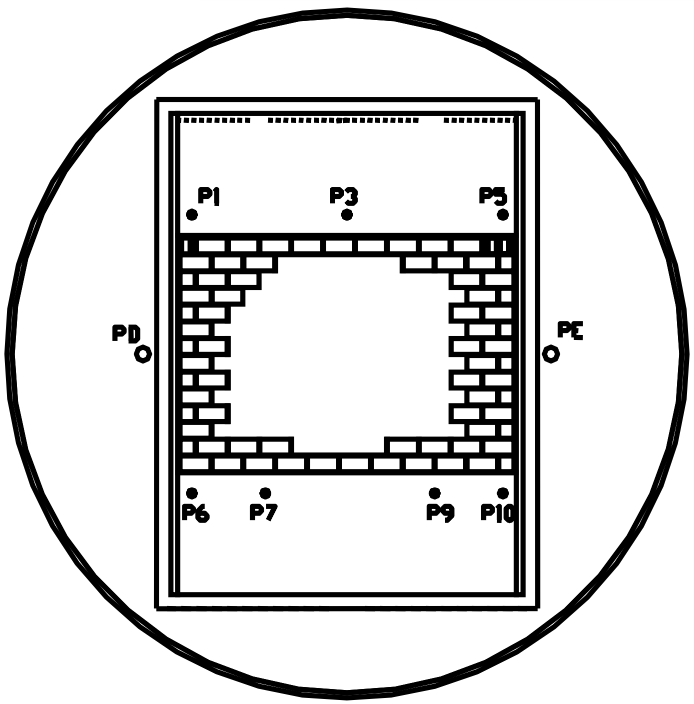


➢ RETROFITTED MATERIALS PROPERTIES

Material	Modulus of Elasticity (MPa/ psi)	Ultimate Strength (MPa/ psi)	Strain at Rupture (%)
Polyurea	229.689/ 33313.7	11.85/1718.3	95
Polyurea with xGnP	12.85/1863.4	4.48/649.8	96
Polyurea with POSS	199.80/28979	13.51/1958.7	113

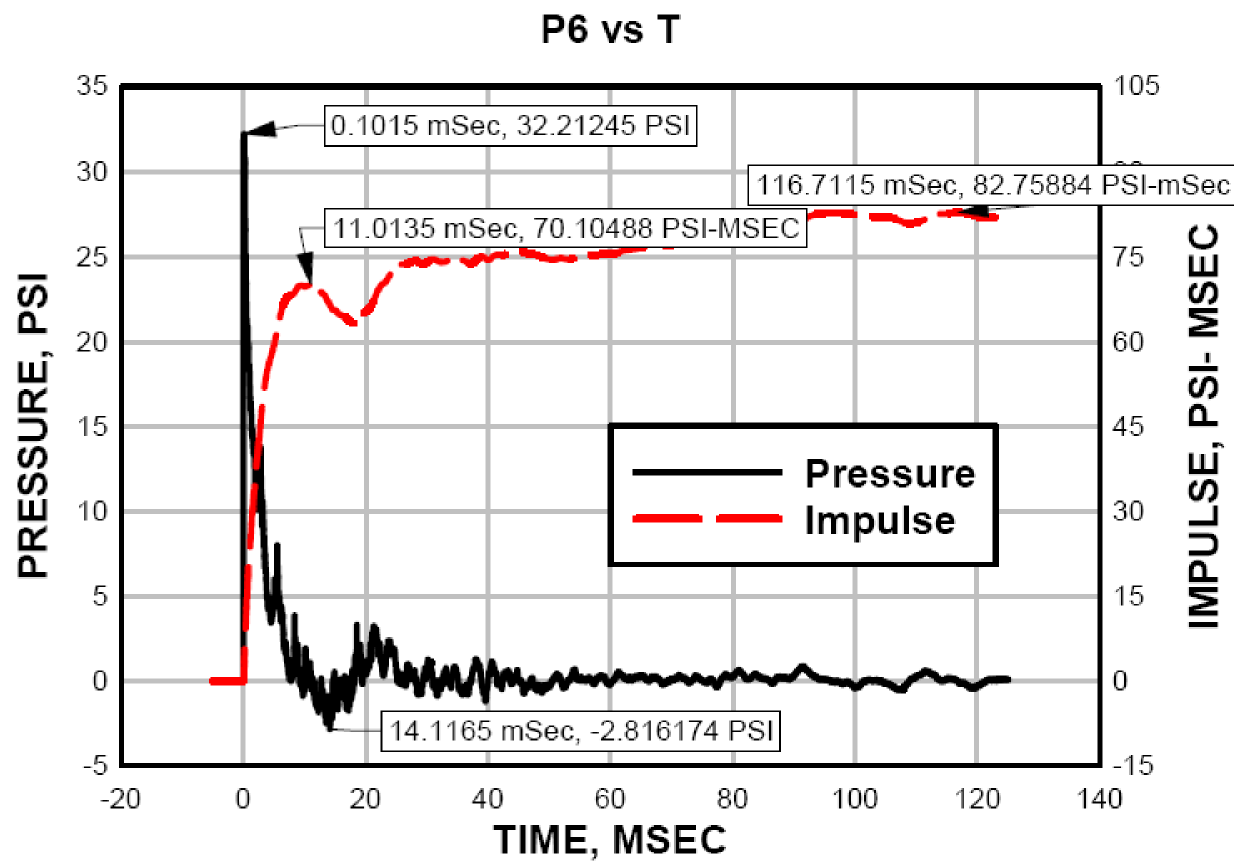
Blast load testing





Gage	P	I
	(psi)	(psi-msec)
P1	33.65	71.7
P3	33.13	71.5
P5	29.5	72.1
P6	32.21	70.1
P7	31.63	71.5
P9	27.95	71.1
P10	30.87	71.6
PD	35.22	72.3
PE	31.6	73.2
Sum	285.76	645.1
Avg	31.75	71.7
IP1	0.37	

Typical pressure-time history and associated impulse time history obtained for Wall 3 using pressure Sensor.



Average values of reflected pressure and impulse for each wall

Wall Number	Pressure kPa, (psi)	Impulse (kPa.ms) (psi.ms)
Wall #1	208.22 (30.20)	366.80 (53.20)
Wall #2	224.91 (32.62)	496.42 (72.00)
Wall #3	218.91 (31.75)	494.35 (71.70)

➢ Experimental results

(a) (b) (c)

Wall #1 (a) Back View Before The Blast Event (b) Back View After The Blast Event
(c) Front View After The Blast Event

(a) (b) (c)

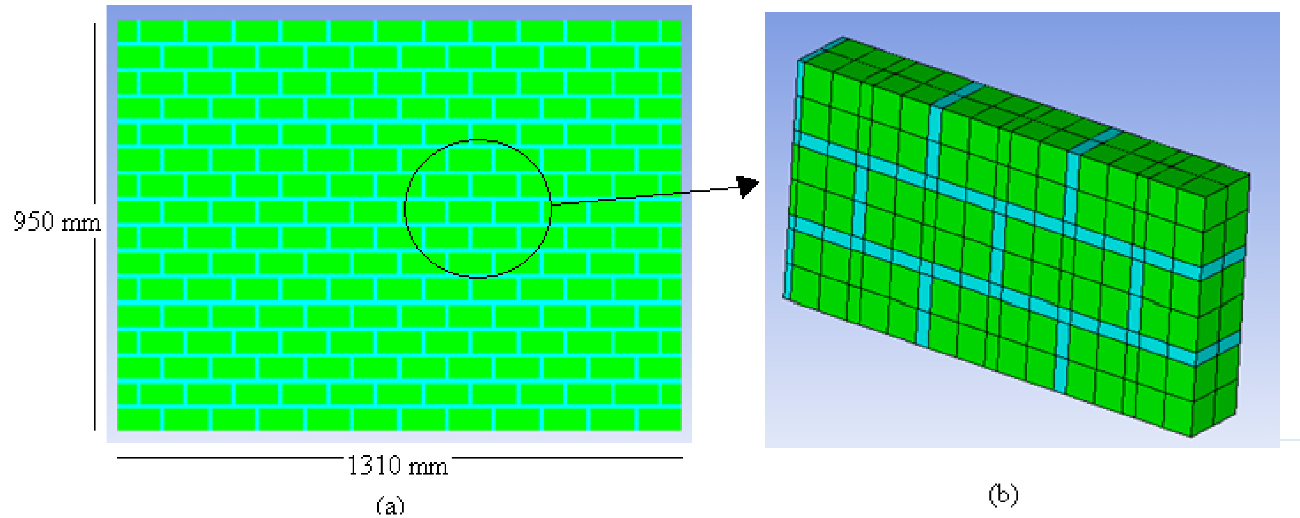
Wall #2 (a) Front View Before The Blast Event (b) Front View After The Blast Event
(c) Back View After The Blast Event

- Experimental results

(a) (b)

Wall #3 (a) back view after the blast event (b) front view after the blast event.

Computational simulations

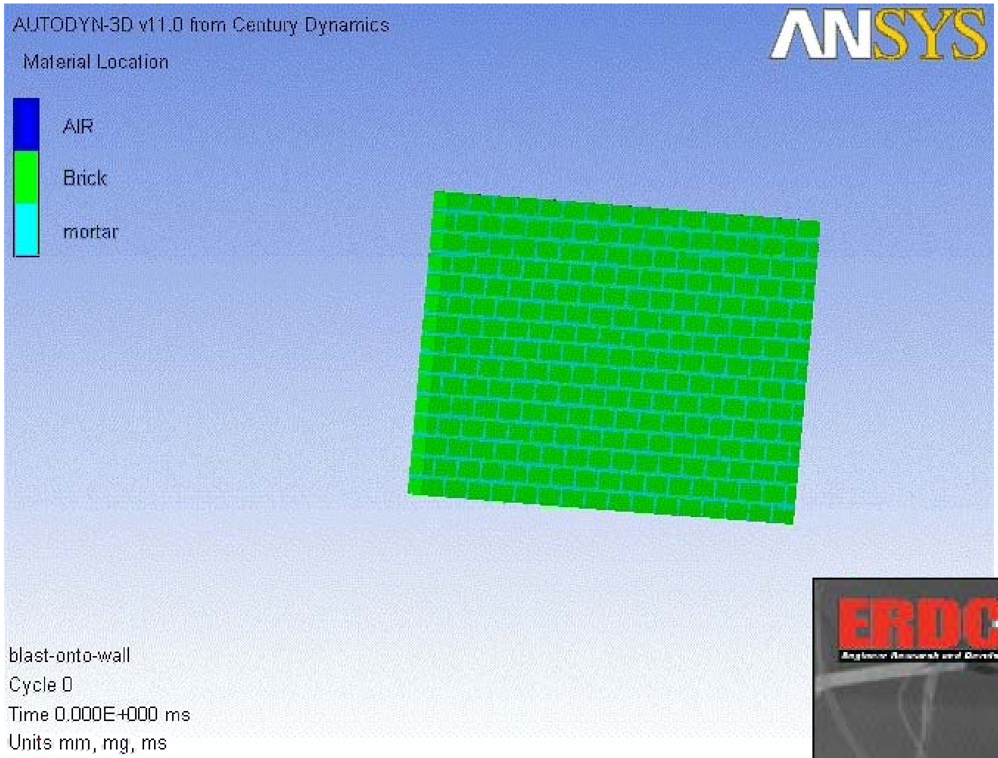


(a) Wall geometry (b) F.E. mesh

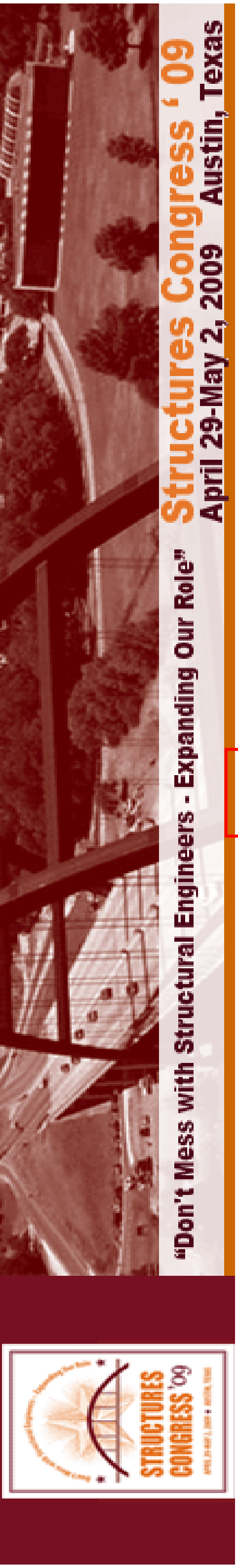
➢Materials Models

Material	EOS	Strength Model	Failure Model
Masonry	Porous	Drucker-Prager	Hydrodynamic tensile failure (P_{min})
Mortar	Compaction	Mo Granular	Hydrodynamic tensile failure (P_{min})
Polyurea	Linear	Johnson-Cook	Principal Strain
Poyurea with POSS	Linear	Johnson-Cook	PrincipalStrain
Poyurea with xGnP	Linear	Johnson-Cook	Principal Strain

FE Model Validation (Un-Retrofitting Walls)



Baseline_CMU_ERDC

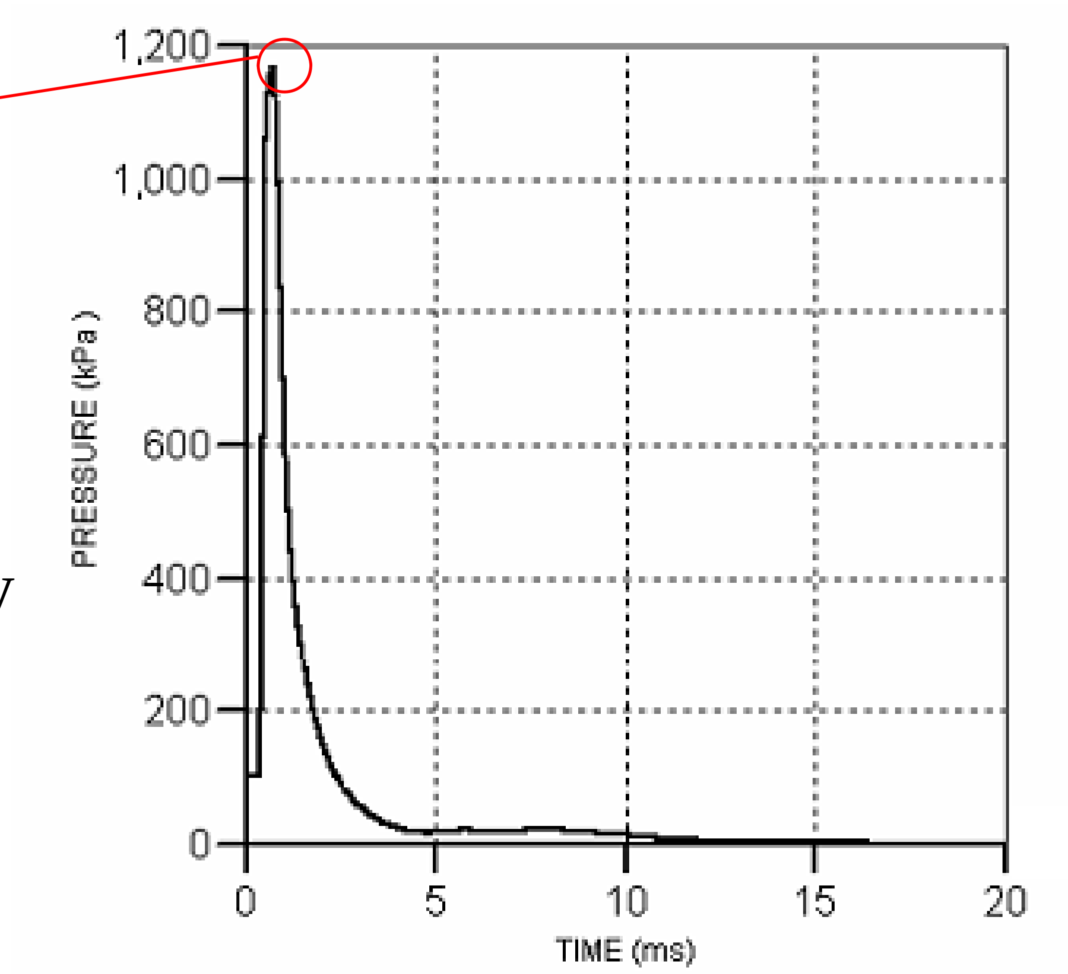


Pressure-Time history due to detonation just before the midpoint of the wall

1164.2 kPa

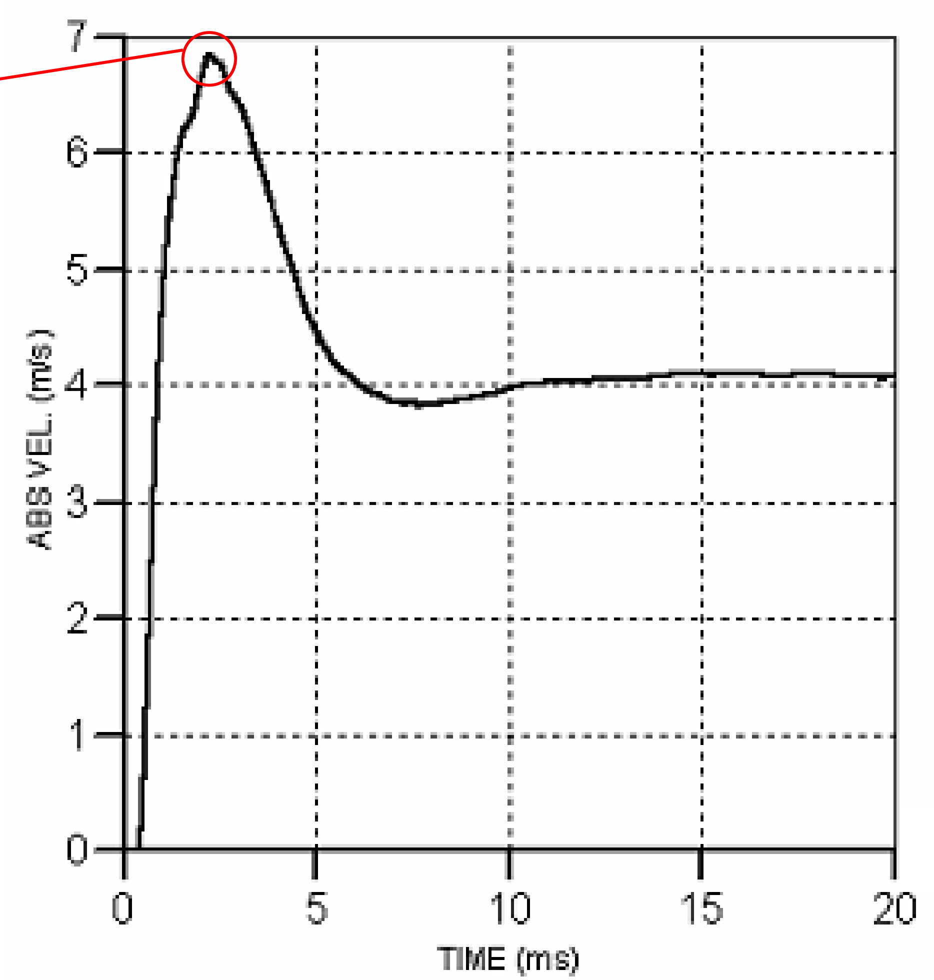
1230.3 kPa

experimentally



Debris velocity at midpoint of the wall

6.834 m/s

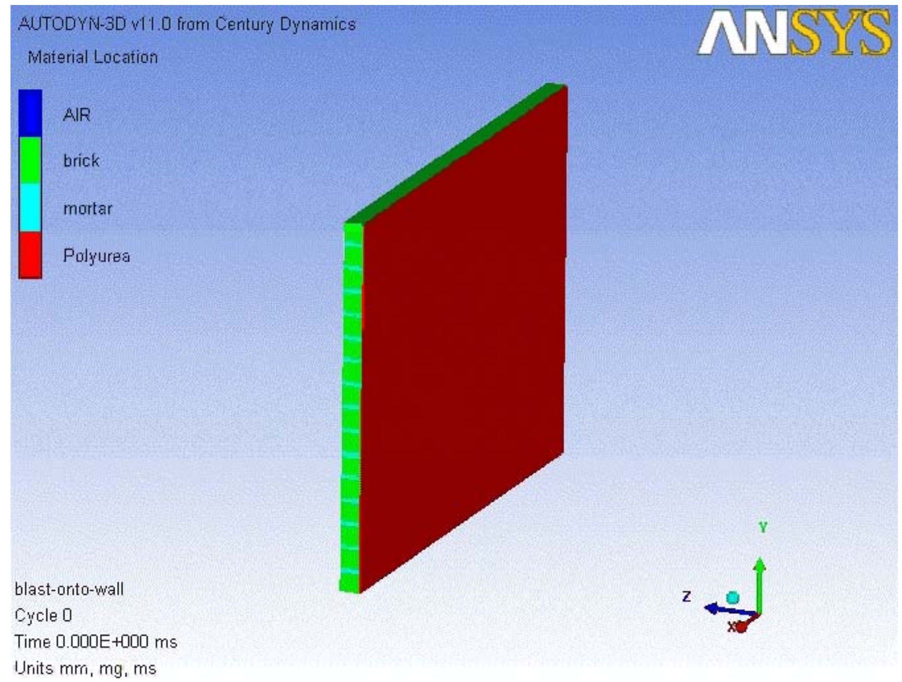


5.91 m/s

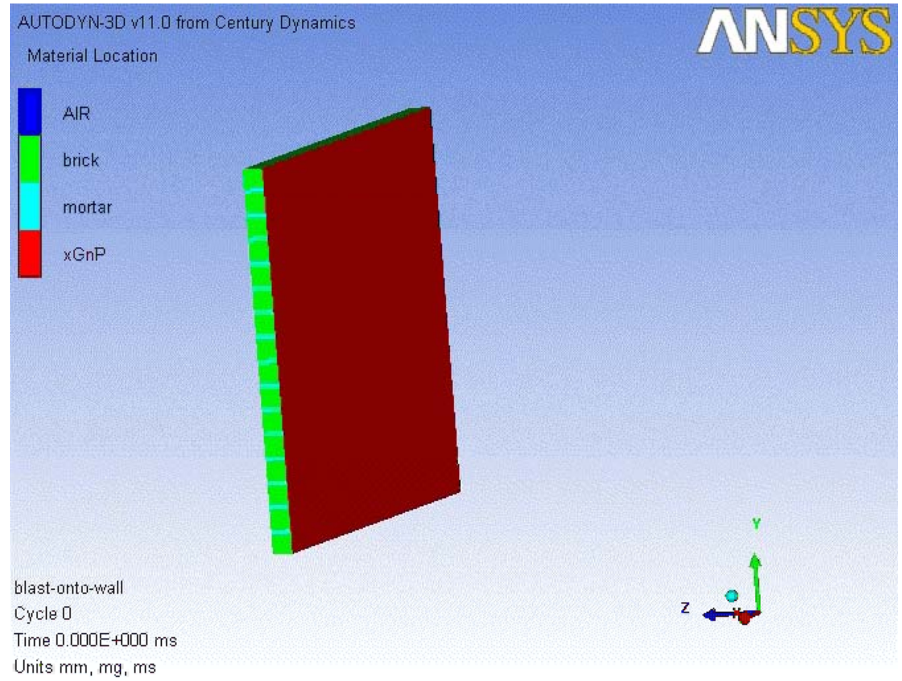
experimentally

CMU wall retrofitted with unreinforced ployurea

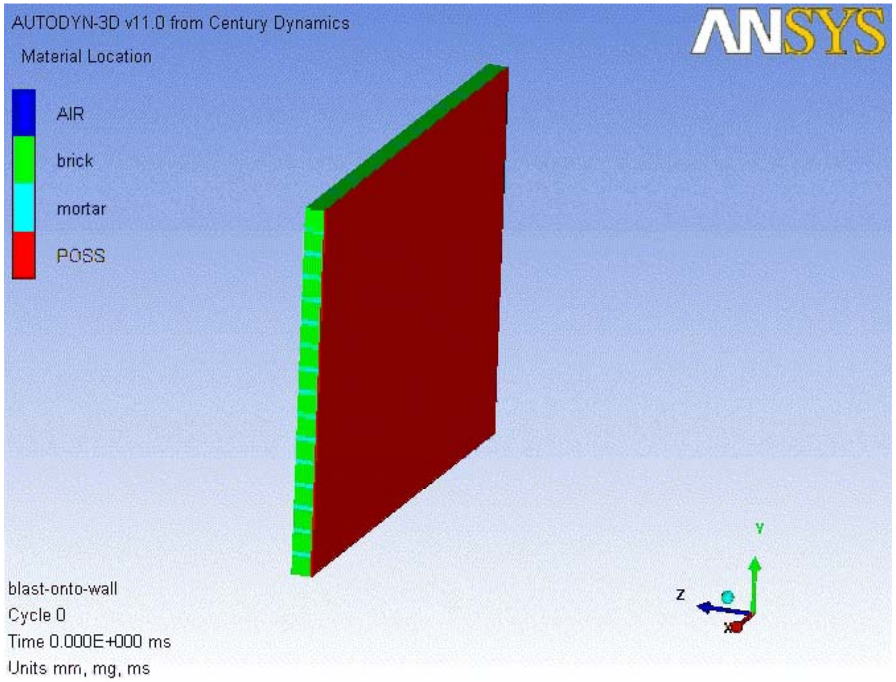
Polyurea exp.



CMU wall retrofitted with reinforced ployurea using xGnP



CMU wall retrofitted with reinforced ployurea using POSS



- Results comparison

Wall Number	Midpoint deflection at failure mm, (in.)		Maximum debris velocity m/s (in/ms)	
	experiment	**FE simulation**	**experiment**	**FE simulation**
Wall #1	91.4 (3.6)	96.27 (3.79)	3.86 (0.15)	5.21 (0.21)
Wall #2	76.4 (3.0)	113 (4.45)	7.47 (0.29)	6.144 (0.24)
Wall #3	120.65 (4.75)	112(4.41)	N.A	N.A

Remarks/Conclusions

- Results from blast experiments showed increase in ultimate flexural resistance achieved by both unreinforced and nano reinforced polyurea retrofit systems applied to URM.

- Whereas nano reinforcing polyurea with POSS nano material improved the performance of the elastomeric retrofit for blast loading, XGnP addition show very little improvement.

- It is important to develop physics-based models to better understand and engineer nano-structured materials for desired properties.

Acknowledgment

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THANK YOU