High Speed Penetration into Low Strength Concrete Target

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NNSA National Nuclear Security Administration

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Outline

- **Phenomenon study on high speed penetration**
  - **(760 - 1220 m/s, 2500 - 4000 fps)**
- **High speed penetration experiments into low strength concrete targets**
  - **(20.7 MPa, 3.0 Ksi)**
- **Penetration simulations with Alegra/Shism, Emu, and Epic**
- **Summary – future plan**

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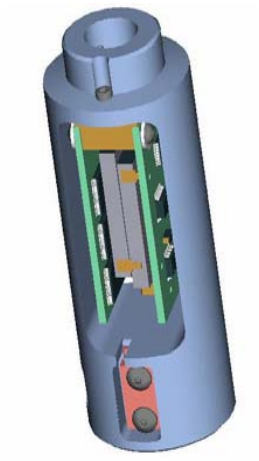
High Speed Penetration Experiments

- **Goal: to demonstrate the survivability of both the 7.62-cm jointed penetrator and the onboard instrumentation in high speed penetration events**
  - **Locate the appropriate gun launcher**
  - **Develop the launch package of petalled pusher/sabot that houses the subscale penetrator instrumented with triaxial data package, 3AMP**
  - **Conduct experiments at normal incidence into low strength concrete targets**



3AMP

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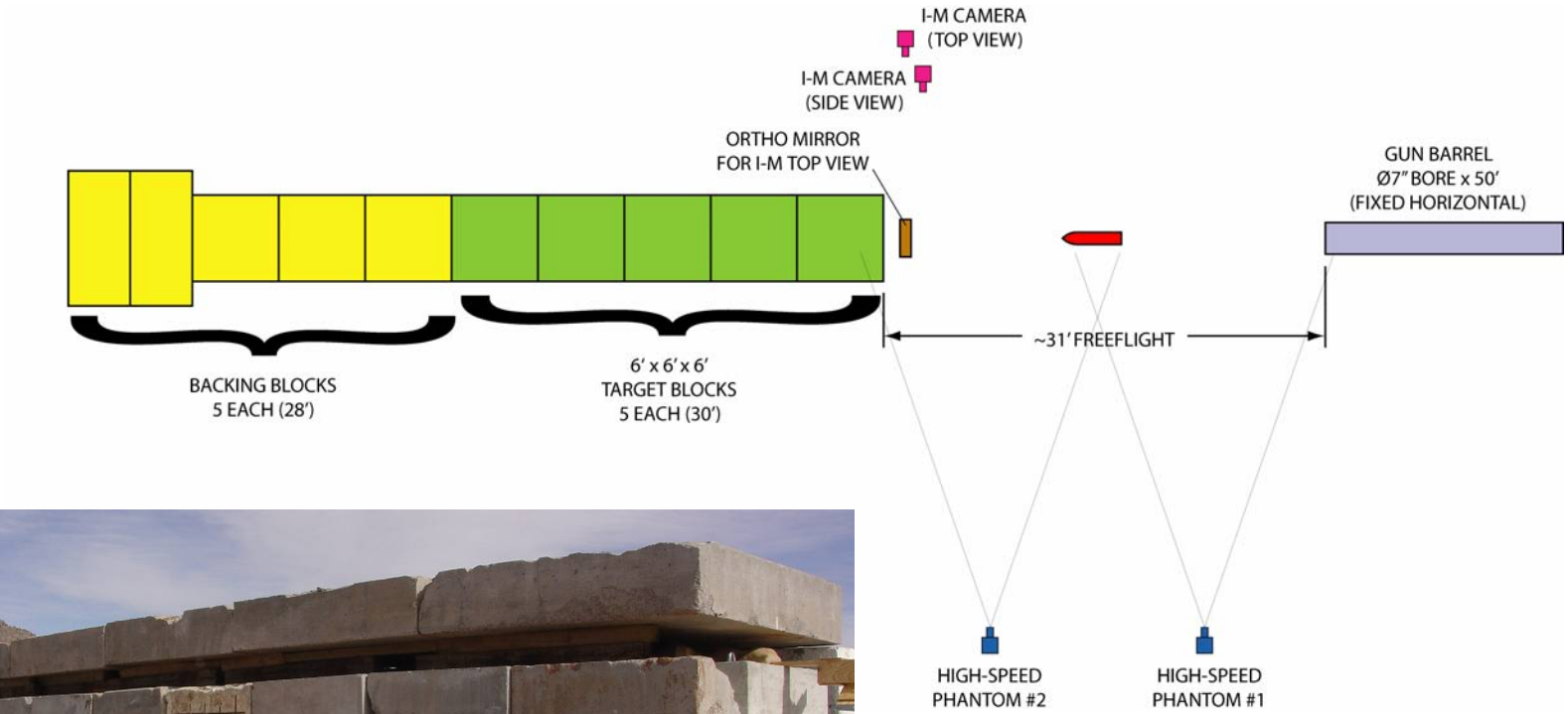
High Speed Penetration Experiments

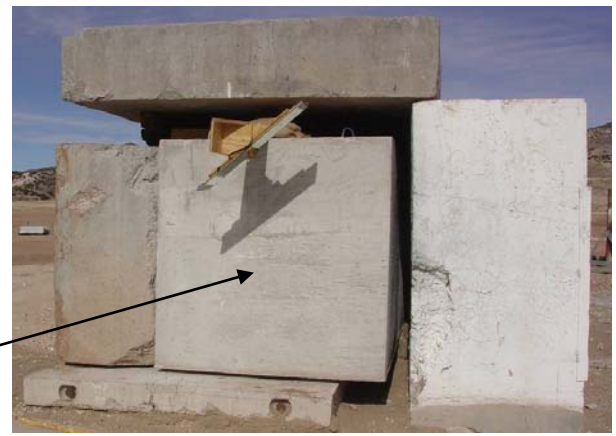
- **Launch facility**
  - **A stationary 17.78-cm (7-inch) powder gun at the Energetic Materials Research and Testing Center (EMRTC) in Socorro, New Mexico**
- **Penetrator design**
  - **A jointed nose of 3 CRH (Caliber Radius Head), 7.62 cm diameter, 53.1 cm long, and a weight of 13.5 Kg**
- **Groutcrete target**

3 KSI Groutcrete UCS DATA			
Block	UCS (psi)		
	7 day	28 day	90 day
1	1715	2520	
2	1410	2335	
3	1335	2195	2785
4	1330	2115	2890
5	---	---	---
6	1380	2325	3040
7	1420	2365	3010
8	1370	2270	3030
9	1480	2335	3010
10	1335	2310	3130
AVERAGE	1419	2308	2985

High Speed Penetration Experiments

Experimental Layout





Impact surface

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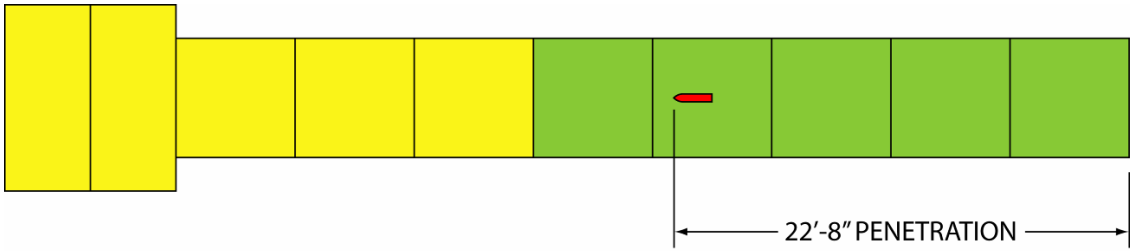
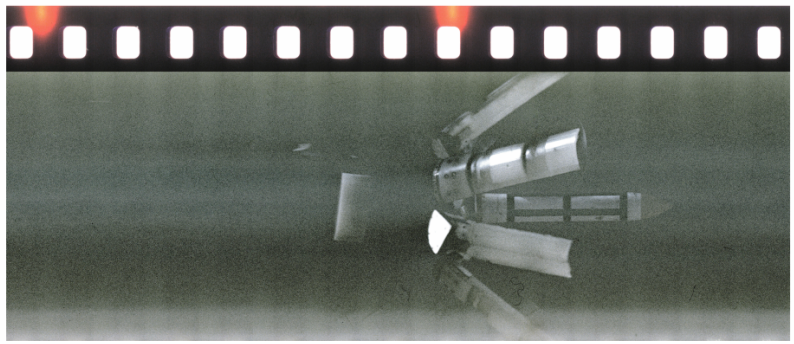
High Speed Penetration Experiments

Results from 1st Experiment





3,637 ft/s IMPACT SPEED - MEASURED FROM THE I-M SIDE VIEW FOOTAGE

- **Impact condition: 1107 m/s (3636 fps) at near normal incidence**
- **Pusher/sabot separation occurred as designed**
- **Depth of penetration: 6.9 m (22.7 ft)**
- **3AMP failed to record meaningful data due to high frequency accelerometer ringing during penetration event**

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High Speed Penetration Experiments

Results from 1st Experiment

Post-test Observations

Target block 4

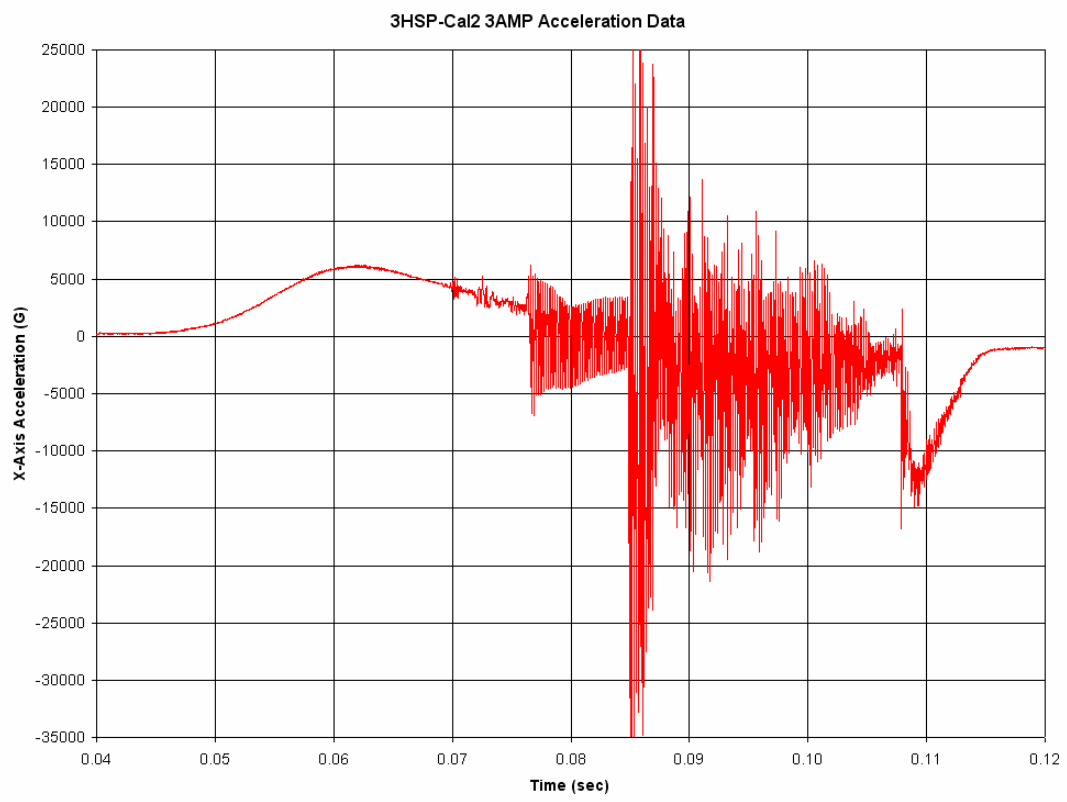
Penetrator final position

- The penetrator and the nose joint survived
  - Nose threads free of damage and turn easily
  - Threads were hand tight after the test
- Penetrator lost 0.65 inches and 2.1 pounds (originally 20.9 inches long and 29.8 pounds)

High Speed Penetration Experiments

Results from 2nd Experiment

- **Impact condition: 1061 m/s (3480 fps) at near normal incidence**
- **Depth of penetration: 6.19 m (20.3 ft)**
- **3AMP recorded meaningful deceleration data**



•The axial deceleration limits were recorded at +25000 g and -35000 g.
• A considerable amount of accelerometer ringing still occurred prior to impact, but it might have not affected the performance of the accelerometer.

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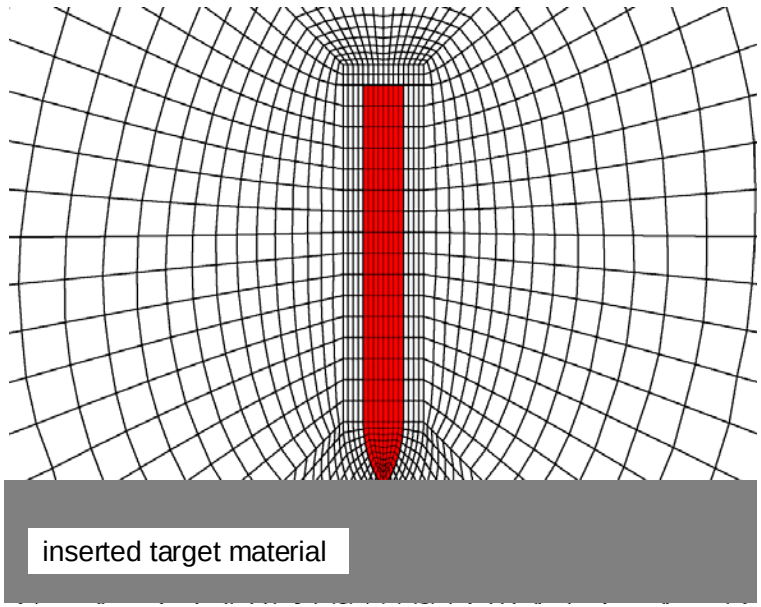
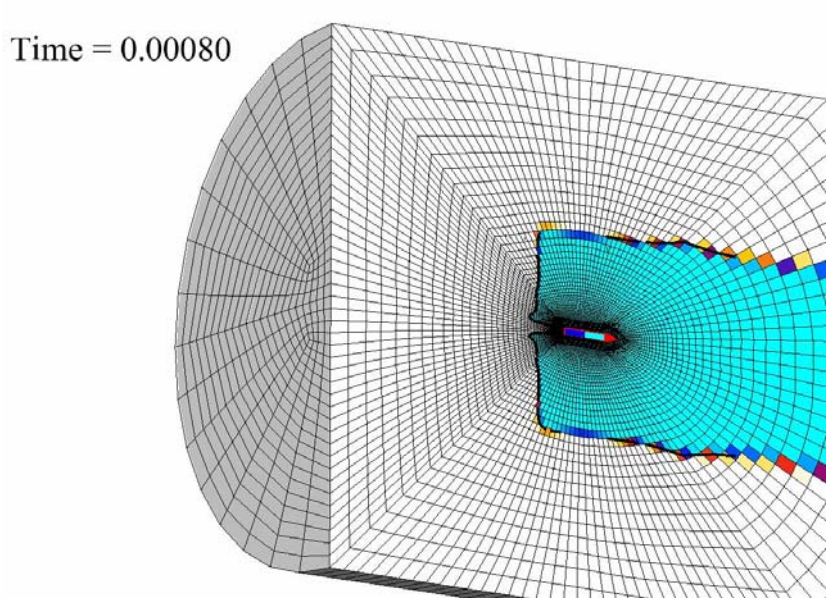
High Speed Penetration Analyses

Alegra/Shism

- **Alegra/shism is a specific algorithm for soft/hard impact conditions. For penetration simulations, the Shism takes the penetrator mesh and interface to be Lagrangian and models the target region as ALE.**



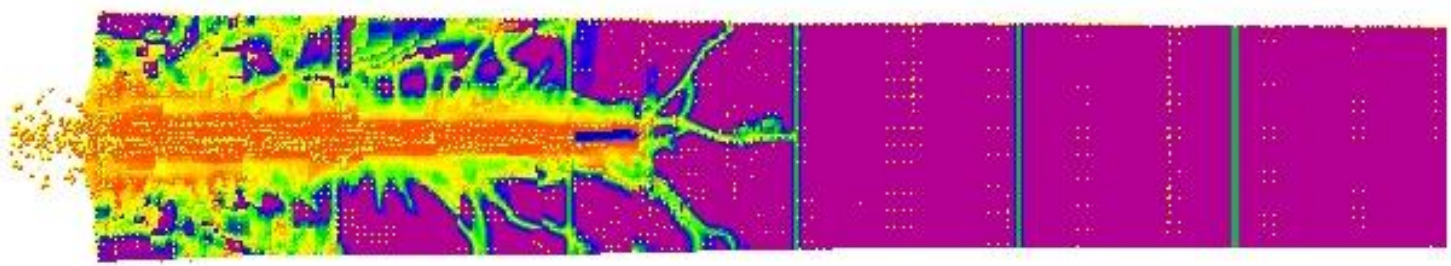


- **Calculated depth of penetration = 4.6 m (Test data: 6.9 m)**

High Speed Penetration Analyses

Emu

- **Emu: A Lagrangian code, based of peridynamic theory, uses a mesh-free, particle approach to describe conservation laws in integral equations.**
- **In the penetration model, the concrete was modeled as a brittle elastic-plastic material, and the penetrator as a rigid projectile.**
- **Analysis results:**
  - **Depth of penetration = 4.25 m (Test data: 6.9 m)**
  - **Peak axial deceleration = 48500 g (Test data: 35000 g)**



Final configuration of penetration event with concrete damage

High Speed Penetration Analyses

Epic

- **Epic: a general purpose finite element code, capable of solving structural dynamic and penetration problems.**
- **Epic has a large library of material models for isotropic and anisotropic behavior and a selected set of failure criteria. It has a special feature to transform distorted 3D elements into meshless particles.**
- **In the high speed penetration model, the concrete target was modeled with 3D elements using the HJC concrete model with a 24 MPa (3.5 ksi) unconfined concrete compressive strength and a 0.34 MPa (50 psi) tensile strength.**
- **Calculated depth of penetration = 3.05 m (Test data: 6.9 m)**

Summary

- **Penetration experiments**
  - **Jointed penetrator design and launch package with petalled pusher/sabot have been developed.**
  - **Onboard 3AMP package survived and recorded deceleration data for high speed penetration experiment with normal incidence into 20.7 MPa concrete target.**
  - **Future tasks include high speed experiments into 39 MPa concrete target.**
- **Penetration analyses**
  - **Sandia has extensive experiences in analyzing penetration events at conventional speeds using Alegra/Shism, Emu, and Epic, and the penetration models perform well.**
  - **However, the high speed penetration models with these codes calculate lower depth of penetration and higher decelerations → target provides much higher penetration resistance.**
  - **New penetration models will be researched and developed to account for radial cracking resulting in material softening of concrete target.**