DISCRETE FIBER REINFORCED POLYUREA SYSTEMS FOR INFRASTRUCTURE REPAIR AND BLAST MITIGATION

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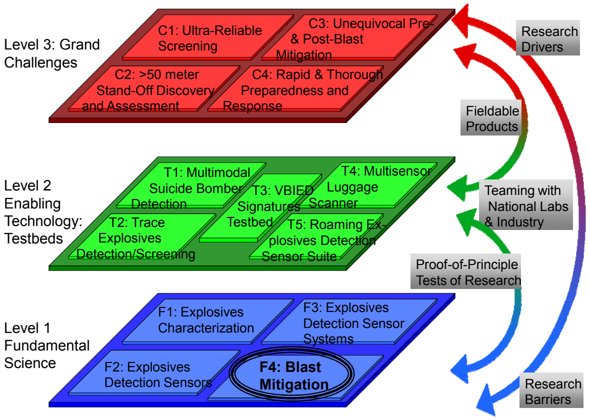
ALERT
Three-Level Strategic Approach



Accomplishments

- Discrete Fiber-Reinforced Polyurea Systems Characterization
- Blast Testing of Two Types of Panels with External Strengthening Systems

Abstract

The first part of this research investigated the development and characterization of different discrete fiber-reinforced polyurea systems for infrastructure applications. The behavior of various systems consisting of several polyureas with different fiber configurations was evaluated by conducting coupon tensile testing. The purpose of further testing was an effort to develop a polyurea system for blast mitigation, multi-hazard, and/or repair-retrofit applications. The addition of fiber to a polymer coating provides improved stiffness and strength to the composite system while the polyurea base material provides ductility. The second part of this study examined the behavior of plain and steel fiber reinforced concrete panels coated with various discrete fiber-reinforced polyurea systems under blast loading. Results from this study will be used to evaluate alternative construction methods and coating systems to protect at-risk structures and their inhabitants.

Objectives of Study

1. Investigate the mechanical properties and performance of different discrete fiber-reinforced polyurea systems under development at Missouri University of Science and Technology (Missouri S&T) in Rolla, Missouri.
2. Investigate the behavior of plain and steel fiber reinforced concrete panels coated with various discrete fiber-reinforced polyurea systems under blast loading.

Challenges and Significance

Research initiatives have been advanced to investigate new materials that can be used for blast mitigation, seismic, and general repair-retrofit applications. Elastomeric polyurea coating possesses several advantageous characteristics, including elasticity, ductility, and energy absorption. Additionally, polyurea is capable of containing spalling and reducing fragmentation during a blast event (Carey & Myers 2009). The development of strengthened polyurea coating systems could yield a multi-hazard retrofit material suitable for life-cycle aging infrastructure.

Test Details

1. The tensile properties of the plain polyurea and composite polymer matrix were determined by conducting coupon testing. In addition, sample ignition loss testing was conducted to determine the fiber reinforcement content. Six various polyureas from two manufacturers were investigated and tested under tension.

Mechanical properties of elastomeric polyureas

Material	Tensile Strength (MPa)	Tensile Strength (psi)	Elongation (%)
Polyurea A	17	2466	480
Polyurea B	14.8	2147	91
Polyurea C	8.3 - 9.0	1200 - 1300	400 - 440
Polyurea D	9.0 - 10.3	1300 - 1500	135 - 150
Polyurea E	13.9	2010	82
Polyurea F	19.3 - 20.7	2800 - 3000	430 - 445

Coupon specimens were fabricated using each elastomeric polyurea and E-Glass fiber by varying fiber content. Coupon specimen fabrication and testing were conducted according to ACI 440.3R-04.

Composite coupon sample undergoing tension

2. Ten panels were fabricated with 0.5 percent reinforcement ratio in each direction. The nominal dimensions of each panel were 1180 x 1180 mm (46.5 x 46.5 in.). Two panel types were investigated including plain concrete and steel fiber concrete. The panels were tested at Missouri S&T experimental mine using the charge weight of 1.36 kg (3 lb) of C4 and 305 mm (12 in.) standoff distance. Polyurea systems were applied on the tension side of each specimen. 6 mm (0.25 in) fiber length was used for the fiber-reinforced polyurea B thru F specimens.

Panel Test Matrix

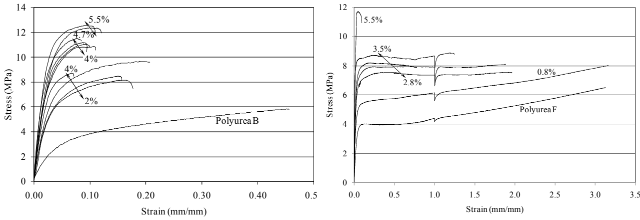
Plain Concrete [90 mm (3.5 in.) thick]
- 1 - control specimen
- 1 - coated with polyurea B
- 1 - coated with discrete fiber-reinforced polyurea B system
- 1 - coated with polyurea F
- 1 - coated with discrete fiber-reinforced polyurea F system

Concrete with Propex Novomesh® 850 [steel fibers]
- same coating configuration and number of specimens as above

Polyurea application process

Important Findings

1. Discrete Fiber-Reinforced Polyurea Specimen Characterization



Stress-strain behavior of 6 mm (0.25 in) fiber-reinforced polyurea B (left) and polyurea F (right) systems.

✓As the fiber content increased for all polyureas fiber-reinforced systems, material strength and modulus of elasticity increased, but ductility decreased compared to the plain polyurea material.
✓In some cases, additional fiber has to be added to some fiber-reinforced systems to achieve a comparable strength level.
✓Polyurea B should be further investigated. By increasing the fiber content to 5%, the strength increased significantly and some minor ductility was gained. In addition, polyurea F should be further investigated as well, due to high ductility and strength (see above).

2. Panel Blast Testing

Reinforced concrete panel with plain polyurea B (left) and reinforced concrete panel with discrete fiber-reinforced polyurea B (right)

✓Plain polyurea coatings contained fragmentation during a blast event. Discrete fiber-reinforced polyurea B system exhibited minor bulging compared to the plain coating due to higher polyurea system stiffness.
✓Discrete fiber-reinforced polyurea F system exhibited tearing due to higher material elongation capability.
✓Steel fiber reinforced concrete exhibited less cracking on the front face compared to plain reinforced concrete.
✓Based on preliminary analysis, discrete fiber-reinforced polyurea B system was determined to be the most advantageous for blast mitigation purposes. Further analysis is still pending.

Research to Reality

1. Develop improved manufacturing processes yielding higher volume fractions of fiber with consistent fiber distribution for higher strengthening capabilities.
2. Numerical simulation using explicit finite element program LS-DYNA of plain reinforced concrete and polyurea coated panel behavior under blast loading is currently in progress.

State of the Art

- Investigated a new strengthening technique for multi-hazard mitigation

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