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Ballistic Impact Response of Foamed-Glass Aggregate: A Lighter Future

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Background

https://www.dvidshub.net/image/6182214/soldiers-unload-and-stack-sandbags-erbil-air-base

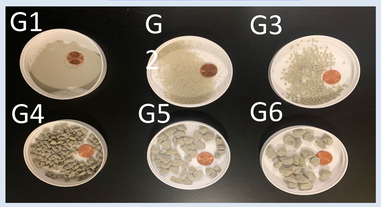
Traditional Sandbags

- Have been used by the United States military and its allies to fortify structures against ballistic impacts for centuries.
- Sandbags are heavy:
  - Impacts on human body
  - Cost to transport if not readily available

Foamed - Glass Aggregate

- Manufactured in the United States from 99% recycled container glass.
- About 80% lighter than sand.
- Resembles pumice stone and comes in various gradations.
- Currently used in several geotechnical and structural applications (lightweight backfill, soil aeration, lightweight concrete, mortar, etc.).

https://www.aeroaggna.com/aerolite-102022



Various grain sizes (penny as a reference)

Research Question

Does this light-weight material have the potential to resist ballistic impact for military applications in temporary protective structures?

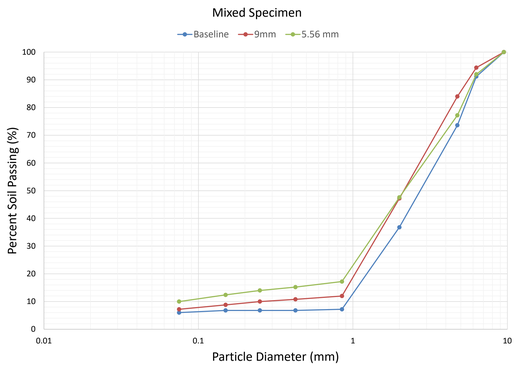
Testing Methodology

- Four different samples of foamed-glass aggregate were tested as well as a standard sandbag for use as the control. The four specimens were:
  - Size G3 (1.19-2.38mm particle size)
  - Size G4 (2.38-4.76mm particle size)
  - Size G5 (4.76-9.40mm particle size)
  - 1:1:1 Mixture of Sizes G3-G5
- Prior to the experiment, the weight, density, and grain-size distribution curves for the sand and foamed-glass mix designs were obtained.
- During the experiment, a high-speed camera captured the entrance/exit of the rounds, which was used to calculate velocities. The camera was placed 9.5' perpendicular to the specimens.
- Each specimen was shot six times using both 5.56mm and 9mm frangible rounds from a distance of 10 feet. The overall test setup is shown in the top photo.
- A sandbag was placed on top of the foamed glass aggregate specimen to act as over-pressure and to minimize movement of the specimen. An additional sandbag was placed behind the specimen, which was used to capture any rounds that penetrated the foamed-glass specimen. (See bottom photo)

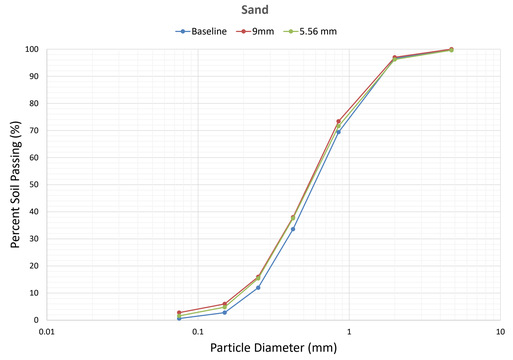
Data/Findings

After the experiment, the following phenomena were measured:

1) An additional sieve analysis was conducted to assess crushing of the foamed-glass aggregate due to the ballistic impacts.
2) The effectiveness of the foamed-glass aggregate in stopping / slowing the round.
   a) If the foamed-glass aggregate completely stopped the round, the average depth of penetration into the foamed-glass specimen was measured.
   b) If the foamed-glass aggregate did not full stop the round, the average reduction in velocity was measured, along with the penetration into the sandbag that was behind the foamed-glass specimen.



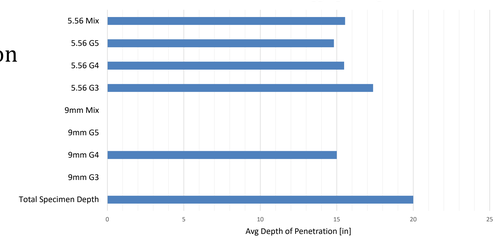
The chart above shows the variation in the sieve analyses that were conducted for the mixed specimen. Similar charts were generated for each of the other three foamed-glass aggregate specimens. The associated image shows how some of the foamed-glass aggregate was crushed due to the ballistic impact.



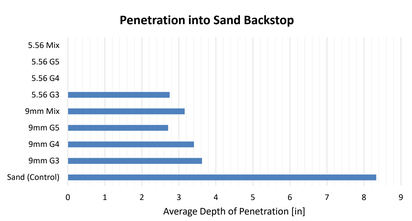
The chart above shows less variation in the sieve analyses for the sand specimen, which indicates that less of the sand particles were crushed due to the ballistic impact.

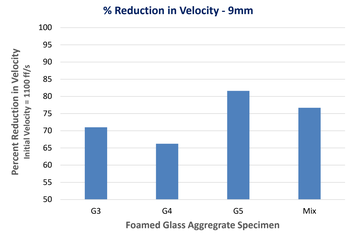
Material/Mix	# of 9mm Rounds Completely Stopped	# of 5.56mm Round Completely Stopped
G3	0	3
G4	2	4
G5	0	6
Mix	0	5

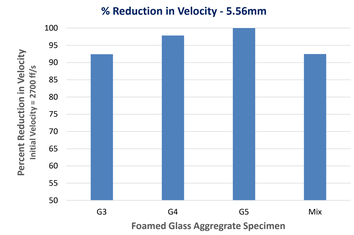
The average depth of penetration was measured for rounds that were stopped by the foamed-glass aggregate specimens. (See chart to the right)



For rounds that passed through the foamed-glass aggregate specimen, the depth of penetration into the sandbag backstop was measured (and compared to the sand alone, which served as the control), along with the reduction in initial velocity.







Impact

- Foamed-Glass Aggregate demonstrated that it does mitigate ballistic impacts and thus should be researched further.
- In an urban environment, protection equipment is required to be shipped (via truck usually) to the necessary location. With a lighter material, more material could be moved in one shipment, meaning less trips traversing potentially dangerous routes.
- If the bags are 80% lighter, it will take less manpower and/or time to construct a fortification, allowing more resources (time and manpower) for other mission sets.
- Capitalizes on the need for constant evaluation of current methods and practices by inspiring innovation.

Future Research

Research associated with the ballistic impact response of foamed-glass aggregate is relatively new (our literature review yielded no previous research), so there are several areas that could be explored:

- Conduct additional tests to validate initial results.
- Test different ammunition (type or caliber).
- Test foamed-glass aggregate response to blast loading.
- Design protective structures comprised of foamed-glass aggregate that are capable of fully stopping various caliber rounds, or other potential applications of foamed-glass aggregate for US military and allies.

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