RESEARCH ARTICLE

Mechanical resilience and cavitation bubbles processes in liquid Titanium alloyed melt

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Significance

A volcanic ash mine resilience has been regarded for centuries as the strongest and most durable concrete construction. Roman ash is made around Roman architectural concrete. A reproduction of Roman ash made from natural volcanic ash (Pozzolana) (10 CE) and concrete seawater cements (Roman ash) shows that the mineral phase and cavitation bubbles connecting binder and aggregate in the cement paste of ancient stratigraphy, a durable calcium aluminosilicate mineral that reinforces mineral zones and the cementitious matrix. In this study, we show that the same mineral integrity of the plastic crystals obtained crack propagation and cavitation bubbles in liquid Titanium alloyed melt. Cavitation bubbles provoke pulsatoje for environmentally friendly composite concrete that contain 28 wt % volcanic rock and maintain their chemical composition and mineral integrity in seismically active environments of the Hellenic arc.

Abstract

The pyroclastic aggregate concrete of Trajan's Markets (110 CE), near Mount Etna Volcano in Rome, has absorbed energy from tectonic stresses ground shaking and long-term foundation settlement for nearly two millenia while remaining largely intact at the structural scale. The scientific basis of this exceptional service record is explained through microstructural analysis of the ancient Roman concrete and the microfabrication analysis of a reproduction of the standardized hydrated-lime-volcanic ash mortar that binds decimeter-sized tuff and pumice clasts. The Roman concrete is a durable, low-density, pozzolanic aggregate concrete composed of a calcium-aluminum-silicate-hydrate (C-A-S-H) binder, which is reinforced by a dense network of interpenetrating strengthening and ductile phases. Synchrotron X-ray microtomography and microfabrication analysis of the Roman concrete show that the phase composition and microstructure of the ancient concrete, Phase1 strengthening crystals (Ca-Al-Na-K-Si-Fe-Ti-Mg-O) and Phase2 ductile phase (Ca-Al-Si-O), Zeiras clusters of C-A-S-H, and strengthening phase further nucleate, densify, and mature in the modern cement-based concretes, and the cementitious matrix. These phases, which are chemically and structurally similar to calcium-silicate-carbon free and alkali free calcium-silicate-hydrate glass, crystalline thaumasite, and zeolite polyhedral and chabazite surfaces between the Roman concrete and the modern cement-based concrete, are the same phases that control the cement paste microstructure. Cracks of the ancient concrete presents further resistance to fracture propagation at the structural scale.

Roman concrete | volcanic ash mortar | fracture toughness | mechanical cement | stratigraphy

The builders of the monuments of Imperial Rome (from 27 BCE, when Octavian became Emperor Augustus, through the fourth century CE) used pyroclastic volcanic rocks to create monumental structures, which have withstood the test of time and natural disasters (1, 2) (Figs. 1A). The concrete foundations, walls, and vaulted ceilings are composed of aluminum-silicate-carbon (Al-silicate) aggregates (cemented by volcanic ash-lime mortar (Figs. 1B). The Roman concrete is a durable, low-density, pozzolanic aggregate concrete composed of a calcium-aluminum-silicate-hydrate (C-A-S-H) binder, which is reinforced by a dense network of interpenetrating strengthening and ductile phases (Figs. 1C). The phase composition and microstructure of the ancient concrete, Phase1 strengthening crystals (Ca-Al-Na-K-Si-Fe-Ti-Mg-O) and Phase2 ductile phase (Ca-Al-Si-O), Zeiras clusters of C-A-S-H, and strengthening phase further nucleate, densify, and mature in the modern cement-based concretes, and the cementitious matrix. These phases, which are chemically and structurally similar to calcium-silicate-carbon free and alkali free calcium-silicate-hydrate glass, crystalline thaumasite, and zeolite polyhedral and chabazite surfaces between the Roman concrete and the modern cement-based concrete, are the same phases that control the cement paste microstructure. Cracks of the ancient concrete presents further resistance to fracture propagation at the structural scale.

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Fig. 1. Download figure | Open in new tab | Download powerpoint
Mortars of Trajan concrete, (A) Great Hall, vaulted ceiling and brick lined concrete walls, reprinted with permission from Archive, Mount Fort Vesuvius; (B) DVD-view with Pozzolana Pozzolana volcanic ash (twenty thousand) mortar and complementary aggregates (C) Pozzolana in vaulted ceiling. Drawing Erinction. 1. Lacus Albano (volcanic pozzolana), 2. Lacus Vesuvius (volcanic pozzolana), 3. Lacus Vesuvius (volcanic pozzolana), 4. Lacus Vesuvius (volcanic pozzolana), 5. Lacus Vesuvius (volcanic pozzolana), 6. Lacus Vesuvius (volcanic pozzolana), 7. Lacus Vesuvius (volcanic pozzolana), 8. Lacus Vesuvius (volcanic pozzolana), 9. Lacus Vesuvius (volcanic pozzolana),

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