

Coquina and the Castillo de San Marcos: The Mystery Behind the Oldest Fort in the United States

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Castillo de San Marcos Fort in St. Augustine, FL has endured many wars and hurricanes for over 330 years. The fort was constructed from a native rock called coquina, which consists of compacted shells, fossils, and sand. In this research, a comprehensive mechanical testing and analysis were performed to determine the energy absorption capability of coquina and sandstone, a material with similar microstructure. Specimens of coquina and sandstone were tested in static and dynamic compression and the force-displacement response was recorded. The deformation of each specimen during the experiments was recorded using a digital camera. The images indicated progressive crushing of coquina over large displacement whereas the sandstone shattered into many fragments. The area under the force-displacement curve for each material, which represents energy absorbed, revealed that coquina had more than twice the energy absorption capability per unit volume compared to sandstone. In the next step, high velocity ball impact experiments were conducted to understand the impact response, simulating the cannonball impacts during the wars. It was observed that the steel ball became embedded in the coquina, progressively crushing the material underneath, whereas the impact on sandstone caused multiple fragments and rebound of the ball. Based on the above experimental observations and microstructural analysis, the mechanisms of energy absorption in coquina were identified as friction, fracture and fragmentation, and progressive crushing, all of which contributed to the dissipation of energy due to the cannon ball impacts. The understanding of the material behavior can be used to design new blast resistant materials for use in structures for protection of sensitive facilities.