International Course on Stone Conservation SC13

SESSION: Mechanical properties of masonry constructions and structural mechanism of decay (part I)

INSTRUCTOR: Giorgio Croci

TIME: Friday, 10th May/ 9:30 – 11:00 (1.5 hours) & 11:30 – 13:00 (1.5 hours)

SESSION OUTLINE

ABSTRACT

Masonry buildings are characterized by their weak tensile resistance, (often considered equal to zero), and their reliance upon compressive strength. Over centuries, this simple fact has determined the shapes and the dimensions of masonry architecture. Pillars and columns perform well due to the high compressive strength of stone (resistance to vertical loads), whereas beams and other elements which span horizontal distances (i.e. architraves, lintels, etc.) are more problematic due to stone's low tensile strength. In architectural and structural design, this strength limitation has resulted in short horizontal spans or the use of wood for beam-like elements where tensile strength is necessary. For example, in Greek and Roman temple architecture, the framing of large and high spaces was achieved through the use of tall columns (of either monolithic or multiple drum construction) closely spaced to one another. The frequent spacing of columns was necessary to accommodate the short span of the horizontal stone elements.

The most important structural development in the history of masonry construction was the arch. During the period of the Roman Empire it was discovered that if a beam is curved and its two edges are supported vertically and prevented from moving outwards horizontally that relevant compressive stresses are induced inside the structure ensuring a new exceptional bearing capacity. From this principle evolved the vault and dome and the ability to cover and span large spaces and long distances. A few examples of architecture indebted to the arch and dome are: the Pantheon in Rome, Hagia Sophia in Istanbul, Brunelleschi's dome in Florence, Saint Peter's Basilica in Rome, and Roman aqueducts. Each of these structures exploits the compressive strength of stone.

Masonry construction failure is seldom a result of compressive weakness but rather is often due to tension stresses. Tension failure is introduced or exacerbated by inappropriate design; uneven distribution of load such as can be induced by settlement or earthquakes; or modifications to original construction. The first signs of stress are cracks. Cracks along construction joints or within the building blocks can be an indicator of disjuncture and consequently can alter the behavior of the structure. However, not all cracks are signs of urgency. A typical pattern of cracks is visible in cracks which run vertically along the meridians of domes. They are produced by even low tension stresses in the circumferential parallels. These cracks are usually not dangerous and can be prevented with circumferential rings (as for example was done on the dome of St. Peter in the middle of the XVIII century).

After reviewing the typical patterns of structural deterioration as they pertain to specific masonry construction typologies, the session will conclude with an overview of some of the most common measures to repair and strengthen historic buildings.

OBJECTIVES

The objectives can be synthesized in two parts:

1) To understand:
    - The structural behavior of structures which primarily function on the principle of compressive stress.
    - How the forms, dimensions, damage and remedial measures are consequences of the strength characteristics of masonry.
    - The behavior of an arch
    - How reading stress cracks and patterns of structural damage correspond to the structural behavior of masonry
2) To learn a methodology for the study and analysis of the structural behavior of historic masonry structures. These include:
    - Historical research, to identify the historic and subsequent construction technologies of buildings; any original or historic damage; and subsequent construction and/or design modifications.
    - Analysis and diagnosis to identify the causes of damage and decay
    - Determination of the safety level of a structure supported by qualitative (observations) and quantitative (mathematical models) analyses
    - Design of remedial measures for stabilization and repair.

CONTENT OUTLINE

- Characteristics of masonry as a structural material; brick and stone (with mortar) and dry laid construction.
- Typical stress distribution characteristics of different masonry construction typologies.
- The arch effect in flat structural elements such as lintels and architraves
- Curved structures - one-dimensional behavior (arches) and bi-dimensional behavior (domes and vaults)
- Damage produced by earthquakes: remedial measures
- Damage produced by soil settlement: remedial measures

READINGS

🕮 = Essential reading material
💻 = Available online

🕮 Croci, Giorgio. 1998. Chapters 1, 4, 5 and 6. In *The Conservation and Structural Restoration of Architectural Heritage*, International series on advances in architecture,. Southampton, UK; Boston, USA: Computational Mechanics Publications.