

1. Research activity (max 1.000 words)

The general objective of this PhD project is to understand the factors that make ancient Roman mortars so hydraulic and durable, with the aim to produce restoration mortars compatible with the ancient ones, highly hydraulic and eco-friendly. Specifically, the aims are to characterize the hydraulic mortars from the inner duct of the aqueducts of ancient Rome and then to experiment new hydraulic mortars, starting from ancient recipes.

Ancient Roman aqueducts are considered extraordinary technological structures even nowadays, because of their efficiency and durability. Ancient Rome was supplied of water by eleven aqueducts: two of these aqueducts, the *Aqua Virgo* (19 BC) and the *Aqua Traiana* (109 AD), are still in use, and supply some famous fountains, among them Fontana di Trevi and Fontana dell'Acqua Paola. Despite the popularity of these aqueducts, there is a lack of scientific studies on the materials that were used for their construction, particularly on the mortars. Many scientific studies have investigated ancient mortars, but only few of them concern the characterization of mortars from ancient Roman aqueducts.

In the restoration field, the general agreement is that the use of cement-based mortars is not recommended, as it causes several damages to cultural heritage, because of their incompatibility. However, restoring a damaged masonry with compatible materials can be quite complicated, because the knowledge of preparation of ancient mortars has fallen into disuse. Some scientific studies have tried to reproduce mortars with materials and characteristics compatible with the ancient ones, opening a new field of research. Another important issue is the ecological impact of modern cement production, that today represents the third-largest source of anthropogenic emission of CO₂: following the European Green Deal, these emissions need to be reduced.

This PhD project consists in:

- i. Stipulation of agreements with the public entities which protect the aqueducts of ancient Rome;
- ii. Sampling of hydraulic roman mortars from the inner part of the duct;
- iii. Characterization of ancient mortars using archaeometric techniques;

- iv. Experimentation of new restoration mortars, hydraulic, eco-friendly and compatible with the ancient ones.

The characterization of the mortars from the aqueducts of ancient Rome will be useful for future restoration, to allow the selection of compatible materials. The experimentation of modern mortars starting from the results of the characterization of ancient ones would allow the production of highly hydraulic restoration mortars, eco-friendly and compatible with the ancient ones leading also to an industrial application.

2. Research products

a) Publications (ISI journals)

- Botticelli, M., Calzolari, L., De Vito, C., Mignardi, S., & Medeghini, L. (2021). Aqua Traiana, a Roman Infrastructure Embedded in the Present: The Mineralogical Perspective. *Minerals*, 11(7), 703.
- Soffritti, C., Calzolari, L., Pepi, S., Fortini, A., Merlin, M., & Garagnani, G. L. (2021). Metallurgical and Statistical Approaches to the Study of Cast Iron Street Furniture. *Metallurgical and Materials Transactions A*, 52(3), 1127-1141.
- Soffritti, C., Calzolari, L., Chicca, M., Bassi Neri, R., Neri, A., Bazzocchi, L. & Garagnani, G. L. (2020). Cast iron street furniture: a historical review. *Endeavour*, 44 (3), 10072.
- Soffritti, C., Calzolari, L., Balbo, A., Zanotto, F., Monticelli, C., Ospitali, F., Fortini, A. & Garagnani, G. L. (2019). Conservation state of cast iron metalworks in European street furniture. *The European Physical Journal Plus*, 134 (9), 424.
- de Ruggiero, A. C., Calzolari, L., Soffritti, C., Varone, A. & Garagnani, G. L. (2018). Cast Iron Metalworks in European Urban Furniture Dating Back to the 19th and the Early 20th Centuries. *Materials Science Forum* (Vol. 941, pp. 663-667). Trans Tech Publications Ltd.
- Soffritti, C., Calzolari, L., Balbo, A., Zanotto, F., Monticelli, C., Fortini, A., & Garagnani, G. L. (2018). Study of the conservation state of European street furniture in painted cast irons. *La Metallurgia Italiana* (n 4, pp 5-16).

b) Publications (NON ISI journals)

- Calzolari, L., Botticelli, M., & Medeghini, L. (2021). Caratterizzazione preliminare dei materiali costruttivi dell'Acquedotto Traiano. In "Aqua Traiana: le indagini tra Vicarello e Trevignano. Nuove acquisizioni e prospettive di studio sull'acquedotto Traiano-Paolo", curated by Cifarelli, F.M., Marcelli, M., Gangemi Editore (978-88-492-4112-9).

c) Manuscripts (submitted, in press)

d) Abstracts

- Calzolari, L., Botticelli, M., & Medeghini, L. (2021). Binder characterization of ancient hydraulic mortars from Trajan's aqueduct. Abstract book XI congresso nazionale AIAR (p 16).

- Calzolari, L., Botticelli, M., & Medeghini, L. & Mignardi, S. (2021). Mortars of the ancient Roman aqueduct Aqua Traiana: an archaeometric study about the aggregate fraction. Abstract book "BeGEO scientist, a young network. I congresso nazionale dei giovani geoscientisti" (p 53).
- Calzolari, L., Botticelli, M., & Medeghini, L. (2020). Characterization of ancient hydraulic mortars from the Roman Aqueduct Aqua Traiana. Abstract book of the conference "Science applications becoming culture" (p 7) (978-883-537-467-1).
- Calzolari, L., Soffritti, C., Bassi, R., & Garagnani, G. L. (2017). Caratterizzazione metallurgica di manufatti artistici in ghisa per arredo urbano tra Ottocento e Novecento. Microscopie (Vol 1, pp 60-61).