

# Fulfilling perceptible and mechanical conditions in heritage mortars through NSGA-II algorithm.

## Heritage masonry and mortar compatibility problem

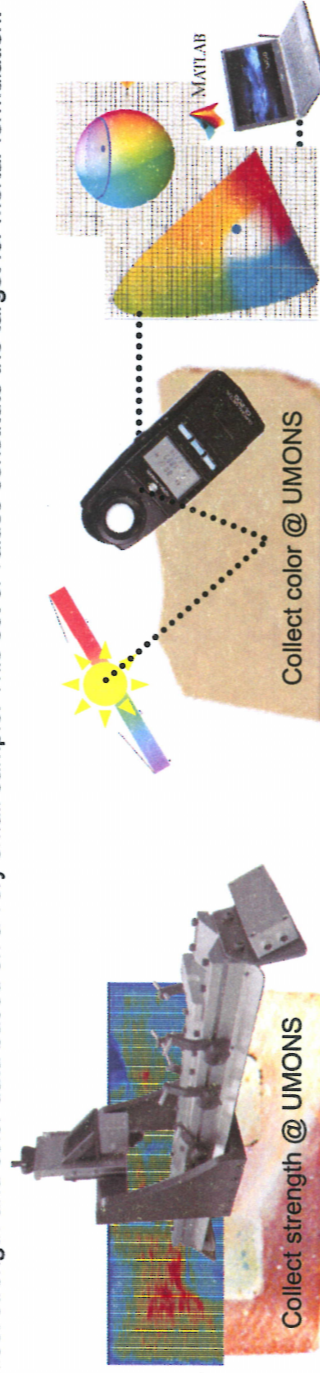
Most of the master pieces of our heritage rely on masonry elements for ensuring their structural stability. Due to intrinsic or extrinsic causes and with ages, alterations phenomena affect most of these parts so that interventions are required. In this framework, civil authorities annually engage important financial means for this purpose. Most of the operations require the contemporary recourse to mortars. Achieving a convenient formulation for these mortars is often delicate as they should reveal compatible with the conserved elements (stone, brick, mortar). In case of incompatibility, specific pathologies appear that can lead to the destruction of materials and make the investments to reveal useless.

Two aspects of the compatibility problem justify the response proposed by the authors: as each case is unique, they propose developing a tool dedicated to computer-aided decision instead of sketching a potentially universal response and as the problem requires satisfying several conditions inside a same analysis, they propose relying on multi-objective optimization for achieving their objective.

## Research project

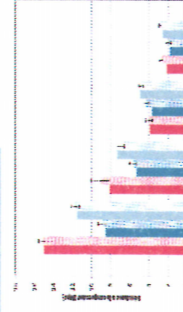
Nowadays and in the daily practice, the formulation of compatible mortars is achieved based on "trial & error" approaches that clearly reveal expensive in time and resources. The usual practical targets tend at satisfying mechanical and perceptible conditions through respectively a value of compressive strength (linked with the modulus of elasticity) and a color target.

Based on specific technologies developed some years ago by the UMONS team (HC tech LAB), it is possible to precisely collect strength and color data based on a very small sample. This set of values constitute the target for mortar formulation.



The Elitist Non-Dominated Sorting Genetic Algorithm NSGA-II algorithm is widely used in various engineering multi-objective optimization problems where discrete as well as continuous variable have to be considered. They rely on the universal principle of natural selection: each generation will produce too much individuals with regard to the welcoming environment. Then, some of these individuals will die and the survival probability depends on the adaptation of each individual.

Strength mixing law  
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As the authors try, by mixing a range of available constituents, to obtain mortar whose properties will be closed to the targeted ones, they propose an intuitive approach. So many mortar formulations are the solutions  $x = [x_1, x_2, \dots, x_n]^T$  expressed through  $n$  design variables that are the types and relative proportions of mortar constituents (type and quantity of sands or mineral powders, type and quantity of binders and quantity of water). An objective function will be defined for each aspect (mechanical aspect, perceptible aspect, ...) the formulation intends to take into account. It requires defining a conventional indicator (EN compressive strength, CIE color triplet, ...) and the function will express the gap, which should be as reduced as possible, between the targeted value and the value corresponding to each individual. The heart of the problem is thus to dispose, for any set of design variable (i.e. given proportion of aggregates, binder and water), to associate an expected value of the indicators. This requires the fundamental establishment of mixing laws but guarantees the universality of the method and may advantageously rely on available published theories. For predicting the compressive strength of mortar, the authors rely on the theory exposed by Sedran & De Larard. For predicting the color of mortar, the Unified Color Theory for Aggregate Mixes (UCTAM) has been developed at UMONS as an extension of Grassman laws. Some complementary constraint functions express the necessity for the sum of each sand fraction of volume to remain under 100 % and the fact that a minimum value of binder is required for being representative of a mortar.



Strength mixing law  
Laboratoire Central des Ponts et Chaussées



Color mixing law  
Université de Mons (HC Tech Lab)

NSGA-II

## Prospects

Considering such encouraging results, complementary investigations are now in progress. Focusing their attention on physical aspects, they interest themselves on the air permeability problem that is recognized as another key parameter in terms of durability. The challenge consists in developing a dedicated method enabling efficient assessment of permeability ranges, based on direct measurements (permeability with N based device) as well as indirect ones (porosity with He and Hg based device or local architecture through  $\mu$ CT). This will allow setting up the basis for a specific objective function,