Initial Developments towards a Unified Protocol of Mortar Preparation for Testing within the SUBLime MSCA Doctoral Network

M. Pułtorak[1] V. Grigorjev[2], N. De Belie[2], P.B. Lourenço[1] and M. Azenha[1]

[1] Department of Civil Engineering, ISISE, Universidade do Minho, Campus de Azurém 4800-058 Guimarães, Portugal
[2] Department of Structural Engineering and Building Materials, Ghent University, Technologiepark-Zwijnaarde, 60, 9052 Ghent, Belgium
e-mail: monika.pultorak@civil.uminho.pt

Abstract. The SUBLime Project (SUstainable Building Lime applications via Circular Economy and Biomimetic Approaches) is a collaborative and interdisciplinary project that brings together 6 academic beneficiaries and 11 industrial partners via a Marie Sklodowska-Curie Action European Training Network – Innovative Training Network. The network provides grounds for research and training opportunities and combines knowledge of academic and industrial members, who craft the future of new construction and conservation of built heritage using lime-based materials. The project covers the main features of lime-based applications in masonry construction, including material characterization, numerical modelling of multi-physics behaviour and development of innovative and sustainable lime-based solutions with added functionality.
The protocol of mortar preparation for testing is used by participants of the SUBLime Project as fundamental guidance on making masonry mortars. The protocol focuses on important aspects of mortar preparation, such as conditioning of constituent materials, mixing and compaction procedures, curing of mortars. Well-detailed descriptions of these aspects are provided to ensure the proper execution of experiments. This comprehensive approach would enable the validation of non-standard experimental methods and repeatability of results of testing of different lime, lime-cement and cement-based mortars.

Keywords: Cement-lime mortars, Experimental protocol, Inter-laboratory tests, Structural masonry, Specimen preparation.

1 Introduction

The SUBLime project - SUstainable Building Lime applications via Circular Economy and Biomimetic Approaches - is an interdisciplinary project that brings together 6 academic beneficiaries and 11 industrial partners. The aim of the project is to develop better understanding and create new applications for lime-based masonry materials[1]. The need for creating protocols for mortar preparation was raised at the

very beginning of this interdisciplinary project. This approach was inspired by successful results in EU funded network COST Action TU1404 “Towards the next generation of standards for service life of cement-based materials and structures”[2,3]. The outcomes of its extended Round Robin Testing (RRT^{+}) program have proven the crucial aspects of consistent preparation of raw materials and specific rules for mixing, casting and curing, which will be implemented in SUBLime.

2 The Protocol of Mortar Preparation for Testing

The Protocol of Mortar Preparation for Testing provides the information about preconditioning of the materials, mixing, moulding and curing of mortar, further described hereafter in sub-sections. As a principle of local representativity and sustainability, materials will be sourced locally at each partner laboratory. Nonetheless, some reference materials may be shared among partners for assessment of comparability of results using the protocol.

2.1 Storage and preconditioning of the materials

The rules for long-term storage of cement and lime are defined to minimize changes in raw materials over duration of the project. After arrival, the bags of binders should be wrapped in three-layer plastic bags with tight knots at the opposite sides of each plastic layer to ensure that moisture ingress is restricted. Binder materials have to be kept in a controlled environment for at least 2 days before mixing at temperature 20±2°C. Aggregates do not need to be stored in any special conditions due to the necessary drying procedure, according to standard EN 1097-5[6]. The sand has to be dried in the oven for 24h at the temperature of 110±5°C. Afterwards, aggregate has to be sealed and kept at the temperature of 20±2 °C until stabilized mass.

2.2 Bulk density test of the raw material

Due to fact that common practice in mixture proportioning for masonry mortars (reflected in EN 1996-1-1 [7]) is based on volumetric proportions, it is desirable to know the bulk density for interconversion with weight-based mixture proportioning, which is of use in laboratory/scientific environments. Choosing the methods for measuring bulk density in loose state is required due to avoiding any compaction. Based on different standards and literature, a simple procedure has been chosen: the CSTB(The Scientific and Technical Center for Building [8]) certificate [9]. The necessary equipment is 3D printed at each Consortium laboratory according to dimensions shown in the certificate.

2.3 Mixing, moulding and curing

The mixing procedure for the SUBLime project is carried out according to the standard

EN 196-1[10] which is repeated in EN 459-2[11]. In standard 1015-2 [12] the procedure is different but members of the SUBLime project will also test cement mortars and lime mortars leading to a universal choice of mixing procedure based on EN 196-1.

Moulding the specimens should be carried out immediately after the mixing of the mortar in accordance with EN 1015-11[13]. Mortars containing high amounts of air lime (>50% mass) have adjusted moulding procedures according to EN 1015-11[13]. Nevertheless, through the preparation of the Protocol there was a debate about different compaction methods. Four compaction methods from EN standards were considered: tamping and tapping from EN 1015-11[13], jolting by jolting table and compaction by vibration table from EN 196-1[10]. Jolting and vibrating tables were considered for their potential to achieve the best repeatability by using automated equipment. Furthermore, reservations about manual compaction methods were present because of many variables affecting the method, such as different force of compaction induced by manual tamper strokes and possibly uneven compaction by tapping the moulds, as well as differences caused by different operators. However, consortium members have agreed to proceed with manual tamping as preferred method due to compaction energy levels comparable to real masonry construction. Effectively, tamped mortars could produce more representative compressive strength and the method is sufficiently repeatable, based on experience of project's partner organizations.

Depending on the composition of the mortar mix there are different curing and demoulding conditions based on recommendations from standards EN 1015-11[13] and EN 196-1[10] (Table 1). Standard EN 196-1 determines the properties of cement but to characterize the masonry or rendering/plastering mortars EN 998-1[14] and EN 998-2[15] need to be followed where conditioning is according to EN 1015-11. The newest version of the EN 1015-11[16] suggests to keep the cement mortars in the mould for 1-3 days. Based on EN 196-1 the decision was made to demould after 1 day. After demoulding the specimens should be kept in 95±5% RH up to 6 days (overall 7 days of curing) and then changed towards 65±5% RH up to the age of testing according to EN 1015-11[16].

Table 1. Curing and demoulding conditions.

Type of mortar	Storage time at a temp 20±2 °C in days		
	Relative humidity		
	95±5%		65±5%
	in the mould	with removed mould	with removed mould
Air-lime/cement mortars with cement mass not exceeding 50% of the total binder mass [13]	5	2	up to testing
Cement and air-lime/cement mortars with mass of air-lime not exceeding 50% of the total binder mass [13]	2	5	up to testing
Cement mortars [10,13,16]	1	6	up to testing

3 Conclusions

The Protocol of Mortar Preparation for Testing was considered as a fundamental step towards the scientific comparability of conclusions and results attained in different laboratories of the same research network. Further preparation of mortars and testing during the project will provide confirmation of the viability of current intents and allow improvements of the protocol to be adopted and reported in subsequent publications.

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