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# The influence of cement on properties of lime mortars

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**Abstract**

The aim of this research is to investigate how cement affects the properties of lime mortars. The usage of pure aerial lime binders reduces the water resistance and mechanic durability of the material. It determines that pozzolan additives or cement have to be used in lime mortar. Mixed cement lime mortar (with increasing amount of cement) were synthesized and their properties tested: density, chemical composition, water absorption rate, compressive strength, resistance to soluble salts and frost resistance. Portland cement can be used as a suitable additive to mortars, to improve their compatibility with the hydraulic and historic mortars.


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*Keywords:* lime mortar, restauration, modulus of hydraulicity.

## 1. Introduction

Principal factor of the sustainability of historic buildings is the usage of applicable, compatible materials in restoration [1]. One of the essential characteristics that make significant impact on water resistance and steam permeability of mortar is porosity and pore structure. It is important criteria for the compatibility assessment [2]. During the 30ies of the last century dense and non-breathable cement mortar incompatible with the historical materials was often used for restoration. The usage of pure aerial lime binders reduces the water resistance and mechanic durability of the material. It determines that lime binders are recommended to be with hydraulic components (active $Al_2O_3$ and $SiO_2$) in order to ensure compatibility with historic mortar. Conformity to historic binders and compatible properties of mortar can be achieved by using lime-cement mixture as a binder.

A series of blended lime-cement mixtures were synthized with growing cement component (up to 10%) in order to determine the changes of mortar properties by adding cement and examining the changes of physical properties of raw and hardened mortar.


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## 2. Materials and methods

Dry building mixtures (mortar for restoration of historic buildings) by the industrial name HML-4 from SIA SAKRET by added different quantity of cement (Aalborg white cement CEM I 52.5 R) component were used in this investigation, Table1.

Five sample series were prepared, based on dry mixture HML-4 with different cement amount: 0, 2, 4, 8, 10%.

Table 1. Dry mix compositions (weight%).

| | HML- 4 | HML-4 + 2% cem. | HML-4 + 4% cem. | HML-4 + 8% cem. | HML-4 + 10% cem. |
|---|---|---|---|---|---|
| Cement | 0 | 2 | 4 | 8 | 10 |
| Lime | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 |
| Fillers (sands) | 84.9 | 84.9 | 84.9 | 84.9 | 84.9 |
| Chemical additives | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |

Table 2. Content of cement in mixture, kg.

| | HML-4 | HML-4 + 2% cem. | HML-4 + 4% cem. | HML-4 + 8% cem. | HML-4 + 10% cem. |
|---|---|---|---|---|---|
| Cement | 0.000 | 0.020 | 0.040 | 0.080 | 0.100 |
| Dry mix | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 |

Flow, density, air content of raw mortar were determined by LVS EN 1015-2:2002 “Methods of test for mortar for masonry - Part 2: Bulk sampling of mortars and preparation of test mortars” [3]. The choice of appropriate water content was important to achieve the optimum consistency of raw mortar and its ability to perform the task. All the samples have to be with the same flow on Hagerman flow-table.

Density of raw mortar was determined by LVS EN 1015-6:2002 “Methods of test for mortar for masonry - Part 6: Determination of bulk density of fresh mortar”. The amount of pores *in* the sample had been determined by LVS EN 1015-7:2002. [4] “Methods of test for mortar for masonry - Part 7: Determination of air content of fresh mortar” [5]. Full chemical analysis was carried out by - LVS EN 196-2:2005: „ Methods of testing cement - Part 2: Chemical analysis of cement” [6].

The mineralogical phases of mortar samples were determined by means of differential thermal and theromgravimetric (DTA/TG) analysis (SETARAM SETSYS Evolution – 1750) and X-Ray diffraction (XRD) analysis (Rigaku Ultima + with CuKα radiation at scanning interval 0-60° (2θ) and speed 2°/min).

Besides water absorption measurements of the samples were made according to NORMAL 7/81:1981, NORMAL 29/88:1988, EN 1936:1998 E, LVS EN ISO 12571:2002, LVS EN 623-2:2001 [7]. Physical characteristics of mortar were calculated using forced water absorption (the samples were boiled in water for 6 hours and weighed in the air and in water).

a) Free water absorvation:

$$Al = \frac{M_{max} - M_0}{M_0} \cdot 100 \text{ , \%;} \quad (1)$$

b) Forced water absorvation:

$$Af = \frac{M_g - M_0}{M_0} \cdot 100 \text{, \%;} \quad (2)$$

c) Apperent density: