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Review

Lime render layers: An overview of their properties

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ABSTRACT

Lime renders are of great importance not only to enhance the appearance of the buildings, but also to protect and preserve old masonries. They constitute a specialized system, composed of several layers, in which each of them depends on the others and carries out some specific functions in order to assure a suitable performance of the whole. Knowledge of the traditional materials and techniques, as well as the *know-how*, is one of the key points in the maintenance and conservation of lime renders and, by extension, of our Heritage. However, the promotion of the use of cement and the industrialization process, which in the case of Spain took place about the 1960's, caused lime mortars to fall into disuse. In this article, classical treatises as well as the state-of-the-art researches were analysed to compile the properties of lime render layers, on the whole. The knowledge of these characteristics is essential to maintain and repair the existing renders as well as to formulate new compatible ones, while assuring their durability and appropriate performance. Lime is the selected binder for these recommendations because it was widely used as drawn from the literature.

1. Research aims

The knowledge of lime renders layers is basic to repair and renovate the existing renders as well as to design new compatible ones. Hence, the aim of the research was to compile properties of the lime renders layers, based on recommendations of classical treatises, last decades' manuscripts as well as empirical experience. It can be considered an add-on to RILEM Technical Committee 203-RHM's paper [1], as it completes the render layers requirements, on the whole, in a referenced and analysed way.

2. Introduction

In order to allow the future generations to enjoy the cultural diversity of our society, we should focus on the conservation and preservation of our built heritage. Hence, the knowledge of traditional materials and techniques is a matter of vital importance, in order to achieve a criterion to select the most appropriate one in any circumstances. This aspect is captured as earlier as 1975 with the Declaration of Amsterdam in which the fact that "steps should be taken to ensure that traditional building materials remain available and that traditional crafts and techniques continue to be used" [2] is emphasized, and are enclosed in the following ICOMOS's documents [3–5].

On the other hand, renders play an essential role in the conservation and maintenance of buildings. Their application has not only an aesthetical reason but also the preservation and reduction of the wall's deterioration, acting as a "sacrifice" element [6,7]. The population's impoverishment and the architect's disdain for hiding the construction were the main reasons for the loss of renders that, in the case of Spain, took place in the postwar period [6,8].

Concerning binders, lime is mentioned in texts as diverse as the Old Testament [9]. Lime renders had been found in archeological sites of Sirian civilizations dated from 4250 B.C. [10], Chinese dinasties from 2000–1700 BC [11,12] as well as in Mayan, Inca and Aztec constructions [13,14]. The finding of a limekiln in old Mesopotamia revealed that limestone calcination appeared in 2450 B.C. [15]. And, the use of lime was extensive up to, in the case of Spain, the middle of 20th century as the literature reveals from the use of limekilns [16–18]. In comparison to other European countries, this delay in the loss of traditional materials and techniques as well as their recovery was due to the isolation of the country.

Hence, a gradual substitution of lime by cement was observed since the end of the 19th century and the beginning of the 20th century, in such a way that applications, originally preformed by lime, began to be overspread by cement. Regarding this, the

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turning point in the use of lime as a binder can be found in the middle of the 18th century when the scientific researches advanced to ascertain the setting process in hydraulic binders. In 1756, Smeaton found out that the main factor for a mortar to set in water was the clay content in the limestones [19–21]. In 1796, Parker patented a hydraulic lime called "Roman cement"or "English cement" and, in 1800, Lesage did so with a mixture of cement and gypsum, meanwhile Sanssure pointed out the amount of silica and alumina to set under water [19]. However, it was not until 1812 that Vicat stated the reasons for the hydraulic behaviour from a scientific point of view. In 1824, Aspdin patented the Portland cement which was similar to Parker's cement [20]. However, according to T. Alberti, "the origins of the real industry of moderns cement are from this period and this patent, since the first factory and the first book on cement manufacture date from 1828" [19]. In 1835, Johnson increased the calcination temperature and sieved the calcined material to get the Portland cement [20]. In treatises, in 1948 Millington mentioned Vicat's findings about the fabrication of artificial hydraulic lime [22]. Then, a whole section of Fontenay's one provided information about the artificial hydraulic lime in which Vicat was quoted: "It's no longer [...] about a laboratory experiment but rather a new art taken almost to perfection" [23]. In 1859, Espinosa dealt with cement at great length and gathered the tests conducted by European researchers. And, in 1870, Valdés described cement as a common material used in renders and plasters [24] and as a leak-proof coating with cement or hydrualic concrete in vaults "in order to prevent leaks from rainwater" [24]. This waterproof property of the cement was highlighted in different parts of the treatise and observed as well in Rebolledo's 1875 treatise. Although, lime was also mentioned in the description about the execution of renders and plasters [25]. In 1923, T. Alberti still showed the importance of aged-slaked lime, although he encouraged the use of hydraulic lime and cement [19]. This exaltation of the cement is also pointed out by Barberot in 1927 who wrote that "cement is commonly used in all the important constructions, mainly when they should be carried out in a short time" [26]. And, in the same year, M. Martínez-Ángel reported the abandonment of the practice of the traditional render [6]. Finally, the technical regulations were the last token of the lime replacement. In 1948, the Spanish standard "Pliego de Condiciones de la Edificación", cement appeared explicitly "to prepare the support, a creamy consistency of pure cement of 3–4 mm of thickness should be applied over the old masonry; and, after three hours, the render could be executed" [27]. Furthermore, in the description of some specific types of render, for instance the petrous ones, white cement is the only binder mentioned, excluding by omission the use of lime [27]. Hence, the exaltation of the properties of cement mortars, their acceptance by the technical regulations as well as the lack of systematic and scientific researches about the traditional lime mixtures, promoted the latter's fall into disuse. It was followed by the loss of traditional techniques and materials which, in renders, was favoured by the secrecy regarding its execution.

In the 1990's, the large amount of damages come about in historical constructions facilitated a return to lime mortars in restoration and renovation works. The properties of cement that were initially praised were not compatible with the old masonries. Especially, their higher mechanical strength, that makes them brittle and stiff, their lower water vapour permeability and the transfer of soluble salts to the support [11,28–49]. In spite of that, in the case of Spain, the conservative trend in construction, the late industrialisation process and the increase of the labour cost explain that most of the renders, that are executed nowadays, are industrial. Hence, traditional renders are allocated to the buildings placed within protected areas, where the town-planning regulations require the conservation and maintenance of the existing renders. This implies the loss of the renderer and plasterer trades as well as the *know-how* [37,50–52]. However, the outstanding problem is the rejection towards traditional materials and techniques because of their handcrafted nature.

In order to prevent the loss of the popular knowledge, scientific researches are brought closer to the society by publications of different Institutions [11,31,32,53] as well as technical committees such as RILEM TC 203-RHM. The present article can be considered an add-on to the paper published by the latter, specifically about renders and plasters [1], as it completes the render layers requirements, on the whole, in a referenced and analysed way. These recommendations are distilled from last decades' researches as well as the empirical experience of the crafts gathered in classical treatises. The knowledge of such characteristics is "de rigueur" to repair and renovate the existing renders and to design new compatible ones.

3. Discussion

Traditional renders are commonly carried out in three "layers", broadly defined [6,11,12,29,31,51,53–79]. For instance, Vitruvius specified three "groups of layers" with a total of seven layers: *trusilatio* (with rubble), three of *arenato* (the higher the total thickness, the higher the durability) and three of *stucco* (sand and marble powder). However, they received different names depending on the author: rough cast, *arenato* and render or *stucco* [6]; rough cast, render and finishing [63], rough cast, *trusilatio* and *arenato* [11] or, in French, *accrochage*, *fond* and *finition* [66]. In contrast, Perrault obviated the base layer and, according to him, the renders are composed of the three layers of sand and lime and three of *stucco* [57], statement that is generally accepted nowadays [80]. In any case, it is clear that renders are composed of different layers which provide more strength and durability [56,57] as well as water protection capacity [81].

Each one of the render "layers" performed a specific function [65]. The base layer is in charge of contributing to join the support and the render as well as to homogenize the surface of the support [29,31,53,56,61,69], which implies the rectification of the irregularities [53,60,62,64]. The intermediate layer corrects the defects of the base and finishing ones [31,56,60,61]. The last one contributes to the colour and finishing of the surface and restricts the weathering and erosion phenomena [29,31,56,60,61,69].

From a mechanical point of view, strength of the mortar should be similar or lower than that of the support over which it is applied. This means not only the masonry wall but also than the previous render layers [11,28,29,66,69,75,82,83]. The placement of a layer with higher strength over one with less strength will cause additional stress over the base layer, provoking its rupture and detachment. At the same time, the deformability capacity and hardness should increase outwards [11,29,71,82] to counteract any variation of temperature and humidity movement as well as in the support [84].

From a hygrothermal point of view, water vapour permeability should be as high as possible. It should increase outwards and will be similar or higher than that of the support [34,52,65,84–86] to promote the water vapour flow through the overall constructive system. Its retention in any of the render layers will imply their detachment and degradation. Moreover, the finishing layer should be able to easily evaporate the rainwater [1,28,76,81,87]. Therefore, the capacity of water absorption, by capillarity, of each layer and the amount of pores should increase outwards [1,31,85,88–90], meanwhile, the pores' size should diminish. The latter guarantees that the water, leaked from the finishing layer, does not seep inwards [1,31,66,87,91]. These criteria have a significant effect on the renders' durability and, from the point of view of the salt crystallization, the render acts as a "sacrifice" element [87].

The aforementioned mechanical and hygrothermal properties entail that the granulometry of the mortars's aggregate should decrease outwards [11,31,53,57,58,61,63,71,76,90,92–101]. Each layer will be executed with gradually finer aggregates, ranging from 0–5 mm in the base layer [31,98] to 0–0.5 mm in a finer finishing one [23–25,27,56–58,60–62,70,102–105]. In the latter, the aggregate can be bristle-sieved [24,62] or silk-sieved [103] and marble powder is frecuently used [24,25,27,51,56–58,62,70,71,102,103,106–109] although, a rough finishing may need a 0–2.5 mm aggregate [11].

The particle size of the aggregate has a clear influence on the amount of binder. The finer the aggregate, the higher its specific surface area and the higher the requeriment of binder. This means that the binder content should be similar or increase outwards [11,66,76,84,85,93,94,99,110,122], in such a way that, in the base layer, the binder content should be higher than in the support. And, it should be gradually whiter and purer outwards [103,104] and, in the finishing layer, aged-slaked lime should be used [23,25,31,62,103,107,108]. This is in accordance with a general rule: the grease blend should be applied over the lean one [11] in aerial binders. However, the contrary should be considered if a hydraulic binder is used [31,52,65,66,81]. Regarding this, opposing advices can be found in the literature because they refer to different types of binders.

The enhancement of mortar shrinkage, due to the increase of binder content, is balanced as well with the aggregate content. In the case of aerial lime mortars, the latter (aggregate content) should be similar or diminished outwards [29,52,53,90,92,93,95,96,99,105,111], ranging from 1:3 to 1:4 (binder:aggregate) by volume, in the base layer [6,9,11,29,53,64–66,68,76,77,93,105,112] to even whitewash, in the finishing layer [12,23,24,53–55,70,78,94,105,110,113]. Although, a small amount of aggregates can be included, depending on the finishing surface roughness of the render [11,23–25,27,34,49,53–55,62,67,76,92,94,102,103,107,114].

From the point of view of its application, thin layers overlapping are better than only one thicker layer [6,11,29,31,52,54,55,64,76,81,86,94,97,110,115–118] to guarantee the adherence of any and all of the layers as well as to delay water penetration while improving drying capacity of the system [81]. Typically a layer is less than 15 mm thin [1,25,26,29,53,63,75,76,81,119] which decreases outwards [11,29,31,34,51,53,57,58,75,90,93,94,99,100]. Moreover, the thickness of the layer should be homogeneous to avoid differential stresses [25,29,31,34,64,85].

With respect to the drying time between each layer, most of the authors suggested that mortar would lose a little of water or be slightly wet before the application of the next one [11,26,31,63,65,71,120]. On the contrary, others insisted on the fact it would be dry [29,53,58,64,104,119] and be preserved from 2 days [29] to 6 weeks [66]. However, if mortars have ability to dry and the water can flow towards the surface, the drying time can be reduced till acquire some hardness and strength, in such a way that the application of the next layer prevents the raising of the previous one. This statement is in accordance to Myrin and Balksten research [123] as well as traditional practice, so the criteria differences can be due to the adaptation to the climatic condition (relative humidity, rainfalls, wind speed and temperatures).

Finally, in order to assure a good adherence, the support's surface area must be rough and porous. Concerning this, support preparation for application of the render is an essential step and depends on the support's nature. Cuts and grooves should be performed in the surface, in the case of mud masonries [23,25,54,55,62,70,103,104,120] as well as in the wooden lattices [11,62]. Meanwhile, the surfaces of the mortar joints should be lightly removed in brick masonries [11,25,26,62,64,71,74,92,121] and stone masonries [11,23,25,62,71,76]. Furthermore, the support should be clean [11,31,53–55,62–64,69,71,76,92,104,105,111,121] and free of loose particles [62,75,119] to avoid the layer's detachment from the adjacent element.

4. Conclusions

Lime renders are one of the key elements for the conservation and maintenance of existing buildings, in which traditional materials and techniques were preserved up to mid-20th century when soon fell into disuse thereafter. In this article, general characteristics of render layers are compiled and analyzed in order to satisfy the requirements of compatibility, durability and conservation of the support over which they are applied. These recommendations are distilled from the last decades researches as well as the empirical experience of the crafts gathered in classical treatises.

According to the literature, the overall render performance depends on the specific function of each layer that makes them up. In this way, mortar deformability and hardness as well as water vapour permeability, water absorption by capillarity and the amount of pores should increase outwards, whereas strength and pores's size should diminish.

Hence, differences in terms of the mechanical and hygrothermal properties of each layer determine the variations in content and particle size of the aggregates as well as the binder's content and type. In addition, basic recommendations for application are highlighted regarding the layer's thickness, their drying time and the nature and conditions of the support.

To summarize, renders can be understood as a specialized system in which the knowledge of the particular properties of each layer and how they affect the overall performance is of great importance. Requeriments should be known to restore and maintain the existing renders, to reproduce the old ones and, even, to design and formulate new blends compatible with the support.

References

[1] K. VanBalen, B. Bicer-Simsir, L. Binda, C. Bläuer, J. Elsen, C. Groot, E. Hansen, R. VanHees, F. Henriques, J. Hughes, E.E. Toumbakari, T. Von Konow, J.E. Lindqvist, P. Maurenbrecher, B. Middendorf, I. Papayianni, S. Simon, M. Stefanidou, M. Subercaseaux, C. Tedeschi, M. Thomson, J. Válek, M.R. Valluzi, Y. Vanhellemont, R. Veiga, Performance and repair requirements for renders and plasters, in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 1359–1363.

[2] ICOMOS, Declaration of Amsterdam, 1975.

[3] ICOMOS, Convención para la salvaguarda del Patrimonio Arquitectónico de Europa, 1985.

[4] ICOMOS, Carta de Conservación y Restauración de Objetos de Arte y Cultura, 1987.

[5] ICOMOS, Charter on the Built Vernacular Heritage, 1999.

[6] J. López, Revestimientos exteriores: enfoscados y revocos, in: VV.AA. Curso de Rehabilitación, COAM, Madrid, 1988, pp. 103–186.

[7] S. Serlio, Tercero y Cuarto Libro de Architectura de Sebastia Serlio Boloñes, Iván de Ayala, Toledo, 1552.

[8] G. Fannelli, R. Gargiani, El principio del revestimiento, Akal, Madrid, 1999.

[9] R.S. Boynton, Chemistry and Technology of Lime and Limestone, Wiley & Sons, USA, 1980.

[10] V. Chu, L. Regev, S. Weiner, E. Boaretto, Differentianting between anthropogenic calcite in plaster, ash and natural calcite using infrared spectroscopy: implications in archaeology, J. Archaeol. Sci. 35 (2008) 905–911.

[11] VV.AA. Guía práctica de la cal y el estuco, Editorial de los oficios, León, 1988.

[12] I. Gárate, Artes de la cal, Munilla-Lería, Madrid, 2002.

[13] A. Cotterell (Ed.), Historia de las civilizaciones antiguas, Crítica, Barcelona, 1985.

[14] E.F. Hansen, C. Rodríguez, Los comienzos de la tecnología de la cal en el mundo Maya: innovación y continuidad desde el preclásico medio al clásico tardío en Nakbe, Petén, Guatemala, in: J.P. Laporte, H. Escobedo, B. Arroyo (Eds.), XV Simposio de Investigaciones Arqueológicas en Guatemala 2001, MUNAE, Guatemala, 2002, pp. 183–187.

[15] A. Moropoulou, A. Bakolas, P. Moundoulas, E. Aggelakopoulou, S. Anagnostopoulou, Strength development and lime reaction in mortars for repairing historic masonries, Cement Concrete Comp. 27 (2005) 289–294.

[16] I. Martínez, E. Barrios, R. Martín, M. Ruipérez, Caleros y canteros, Diputación de Salamanca, Salamanca, 1987.

[17] M. López, J.J. Castillo, P. Candela, Inventario de Patrimonio Industrial de la Comunidad de Madrid, DGP-CAM, Madrid, 2000.
[18] J.M. Muñoz, P. Schnell, Hornos de cal en Vegas de Matute (Segovia). El conjunto de Zancao, siglos XVI-XVIII, JJCL, Salamanca, 2007.
[19] T. Alberti, Propiedades y fabricación de cales y cementos, Núñez Samper, Madrid, 1923.
[20] F. Alou, V. Furlan, Materiaux de Construction, École Polytechnique Federale de Lausanne, Lausanne, 1989.
[21] A.E. Charola, F.M.A. Henriques, Hydraulicity in lime mortars revisited, in: P. Bartos, C. Groot, J.J. Hughes (Eds.), RILEM Workshop on Historic Mortars, RILEM, France, 2000, pp. 95–104.
[22] J. Millington, Elementos de arquitectura, Imprenta Nacional, Madrid, 1848.
[23] M. Fontenay, Novísimo manual práctico de las construcciones rústicas, Calleja, López y Rivadeneyra, Madrid, 1858.
[24] N. Valdés, Manual del Ingeniero y Arquitecto, Gabriel Alambra, Madrid, 1870.
[25] J.A. Rebolledo, Construccion general, J. Antonio García, Madrid, 1875.
[26] E. Barberot, Tratado Práctico de Edificación, GG, Barcelona, 1927.
[27] DGA, Pliego de condiciones de la edificación, MinisterioVivienda, Madrid, 1948.
[28] A. Baglioni, G. Guarnerio, La rehabilitación de edificios urbanos, GG, Barcelona, 1988.
[29] J. Ashurst, N. Ashurst, Mortars, plasters and renders, Gower Technical Press, Southampton, 1989.
[30] M. Olivier, Restauration des structures en terre crue en fonction de leur technologie de construction, in: M.J. Thiel (Ed.), Conservation of Stone and Other Materials, E&FnSpon, London, 1993, pp. 673–680.
[31] École d'Avignon, Techniques et pratique de la chaux, Eyrolles, Paris, 1996.
[32] P. Gibbons, Lime, in: I. Maxwell, N. Ross (Eds.), Conference Proceedings, Historic Scotland, Edinburgh, 1987, pp. 101–108.
[33] C. Rodriguez, E. Hansen, W.S. Ginell, Calcium hydroxide crystal evolution upon aging of lime putty, J. Am. Ceram. Soc. 81 (1998) 3032–3034.
[34] S. Newsom, P. Gibbons, S. Brown, External lime coatings on traditional buildings, Historic Scotland, Edinburgh, 2001.
[35] E. Ontiveros, Programa de normalización de estudios previos y control de calidad en las intervenciones: morteros empleados en construcciones históricas, IAPH 34 (2001) 78–89.
[36] L.B. Sickels-Taves, M.S. Sheehan, Specifying historic materials: the use of lime, in: D. Throop, R.E. Klingner (Eds.), Masonry, ASTM, USA, 2002, pp. 3–22.
[37] J. Lanas, J.I. Alvarez, Masonry repair lime-based mortars: Factors affecting the mechanical behaviour, Cement Concrete Res. 33 (2003) 1867–1876.
[38] C. Montoya, J. Lanas, M. Arandigoyen, P.J. García-Casado, J.I. Álvarez, Study of ancient dolomitic mortars of the church of Santa María de Zamarce in Navarra (Spain): comparison with simulated standards, Thermochim. Acta 398 (2003) 107–122.
[39] C. Montoya, J. Lanas, M. Arandigoyen, P.J. García-Casado, J.I. Álvarez, Mineralogical, chemical and thermal characterisations of ancient mortars of the church of Santa Maria de Irache Monastery (Navarra, Spain), Mater. Struct. 37 (2004) 433–439.
[40] C. Atzeni, A. Farci, D. Floris, P. Meloni, Effect of aging on rheological properties of lime putty, J. Am. Ceram. Soc. 87 (2004) 1764–1766.
[41] J. Lanas, J.L. Pérez, M.A. Bello, J.I. Álvarez, Mechanical properties of masonry repair dolomitic lime-based mortars, Cement Concrete Res. 36 (2006) 951–960.
[42] J. Lanas, R. Sirera, J.I. Álvarez, Study of the mechanical behavior of masonry repair lime-based mortars cured and exposed under different conditions, Cement Concrete Res. 36 (2006) 961–970.
[43] R.M.H. Lawrence, T.J. Mays, P. Walker, D. D'Ayala, Determination of carbonation profiles in non-hydraulic lime mortars using thermogravimetric analysis, Thermochim. Acta 444 (2006) 179–189.
[44] M.P. Seabra, J.A. Labrincha, V.M. Ferreira, Rheological behaviour of hydraulic lime-based mortars, J. Eur. Ceram. Soc. 27 (2007) 1735–1741.
[45] E. Ruíz, C. Rodríguez, Rheology and microstructure of lime putty implications in the design of mortars for conservation purposes, in: VV.AA. Proceedings IX CICOP, CICOP, Sevilla, 2008, pp. 153–158.
[46] M.P. Seabra, H. Paiva, J.A. Labrincha, V.M. Ferreira, Admixtures effect on fresh state properties of aerial lime based mortars, Constr. Build. Mater. 23 (2009) 1147–1153.
[47] A. Sepulcre, F. Hernández, Assessment of phase formation in lime-based mortars with added metakaolin, Portland cement and sepiolite, for grouting of historic masonry, Cement Concrete Res. 40 (2010) 66–76.
[48] K. Balksten, Understanding Historic Mortars and their Variations – a Condition for Performing Restorations with Traditional Materials, in: J. Válek, C. Groot, J.J Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 11–18.
[49] J. Bolton, Irish Medieval Mortars: Implications for the Formulation of New Replacement Mortars, in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 19–27.
[50] A. Moropoulou, A. Bakolas, S. Anagnostopoulou, Composite materials in ancient structures, Cement Concrete Comp. 27 (2005) 295–300.
[51] G. Biscontin, M. Piana, G. Riva, Research on limes and intonacoes of the historical Venetian architecture. Characterization of some "Marmorino" intonacoes from the 16th to the 17th century, in: VV.AA (Ed.), Mortars, Cements and Grouts used in the Conservation of Historic Buildings, ICCROM, Rome, 1982, pp. 359–373.
[52] E. Marie-Victorie, P. Bromblet, A new generation of cement-based renderings: an alternative to traditional lime based mortars? in: L.G.W. Verhoef, F.H. Wittmann (Eds.), Proceedings of the international workshop on Urban Heritage and Building Maintenance VII, Aedificatio Publishers, Germany, 2000, pp. 371–393.
[53] P. Gibbons, S. Newsom, E. Whitfeld, Care and Conservation of 17th Century Plasterwork in Scotland, Historic Scotland, Edinburgh, 2004.
[54] F.L. San Nicolas, Arte y Uso de Architectura, S.l. s.f., Madrid, 1639.
[55] F.L. San Nicolas, Segunda parte del Arte y Uso de Architectura, S.l. s.f., Madrid, 1667.
[56] L.B. Alberti. Los Diez Libros de Architectura de L. Baptista Alberto, Alfonso Gómez, Madrid, 1582.
[57] J. Ortiz y Sanz, Los diez libros de Archîtectura de M. Vitruvio Polión, Imprenta Real, Madrid, 1787.
[58] C. Perrault, Compendio de los Diez Libros de Arquitectura de Vitruvio, Gabriel Ramírez, Madrid, 1761.
[59] C. Rieger, Elementos de toda la Architectura Civil, Joachin Ibarra, Madrid, 1763.
[60] B. Bails, Elementos de Matemática, Joaquín Ibarra, Madrid, 1796.
[61] P.C. Espinosa, Manual de construcciones de Albañilería, Severiano Baz, Madrid, 1859.
[62] F. Ger y Lóbez, Tratado de Construcción Civil, La Minerva Extremeña, Badajoz, 1898.
[63] J. DeCusa, Revestimientos, CEAC, Barcelona, 1974.
[64] A. Kohl, K. Bastian, Tratado moderno de albañilería, José Montesó, Barcelona, 1975.
[65] V. Furlan, N. Kohler, Les différents types de crépis et enduits extérieurs Chronique des matériaux de construction 7 (1981).
[66] V. Furlan, Experiences pratiques avec des crepis a base de chaux, in: VV.AA (Ed.), Mortars, Cements and Grouts used in the Conservation of Historic Buildings, ICCROM, Rome, 1982, pp. 9–18.
[67] Y.M. Froidevaux, Techniques de l'Architecture Ancienne. Construction et restauration, Pierre Mardaga, Belgium, 1985.
[68] M.V. Catalina, Los colores de Madrid, Revista de información Cultural 76–77 (1990) 37–44.
[69] M.J. Guinea, Consolidación, mejora y nuevas técnicas de construcción con tierra, in: VV.AA. Jornadas sobre Restauración y Conservación de Monumentos, IPC, Madrid, 1991, pp. 135–141.
[70] J.P. Adam, La construcción romana: materiales y técnicas, Ed.Oficios, León, 1996.
[71] C. Barahona, Técnicas para revestir fachadas, Munilla-lería, Madrid, 1999.
[72] F. Bermúdez, M.P. Ruiz, Estudio estratigráfico de enlucidos, IAPH 33 (2000) 133–139.
[73] J. Orantos, Recuperación de esgrafiados, BIA 219 (2002) 99–114.
[74] L. Rampazzi, R. Bugini, St. Lorenzo Basilica in Milan: Integral approach to characterisation of historical mortars, E-Preservation Science 3 (2006) 21–26.
[75] UNE-EN-13914-1, Diseño, preparación y aplicación del revoco exterior y del enlucido interior, AENOR, Madrid, 2006.
[76] M.R. Veiga, Intervenções em revestimentos antigos: conservar, substituir ou.destruir, Materiais de Construção (2006) 34–39.
[77] W. Scholz, W. Hiese, Baustoffkenntnis, Bücher Werner Verlag, Germany, 2007.
[78] A. Brysbaert, Painted plaster from Bronze Age Thebes, Boeotia (Greece): a technological study, J. Archaeol. Sci. 35 (2008) 2761–2769.
[79] C. Borgen, A.S. Silva, M.R. Veiga, Ancient Mortars Under Action of Marine Environment: a Physico-Chemical Characterization, in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 29–41.
[80] J. Hoz, L. Maldonado, F. Vela, Diccionario de construcción tradicional, Nerea, San Sebastián, 2003.
[81] M.R. Veiga, Characteristics of repair mortars for historic buildings concerning quantified hygric requirements, in: C. Groot (Ed.), Proceedings 078: Repair Mortars for Historic Masonry TC RMH, RILEM, France, 2009, pp. 305–315.
[82] H. Künzel, K. Sedlbauer, External rendering: a historical perspective on changes in demands on renderings and their composition, in: L.G.W. Verhoef, F.H. Wittmann (Eds.), Proceedings of the international workshop on Urban Heritage and Building Maintenance VII, Aedificatio Publishers, Germany, 2000, pp. 9–17.
[83] ANFAPA, IteC, Morteros monocapa. Revestimientos de fachadas, IteC, Barcelona, 2008.
[84] I. Holmström, To reintroduce lime technology: Experiences in Sweden, in: L.G.W. Verhoef, F.H. Wittmann (Eds.), Proceedings of the international workshop on Urban Heritage and Building Maintenance VII, Aedificatio Publishers, Germany, 2000, pp. 133–150.
[85] S. Chandra, L. Berntsson, A. Svärd, Restoration of the Torpa Stone House, in: L.G.W. Verhoef, F.H. Wittmann (Eds.), Proceedings of the international workshop on Urban Heritage and Building Maintenance VII, Aedificatio Publishers, Germany, 2000, pp. 123–133.
[86] A. Reichel, A. Hochberg, C. Köpke, Enlucidos, revocos, pinturas y recubrimientos, GG, Barcelona, 2004.
[87] C. Groot, J. Hughes, K. VanBalen, B. Bicer-Simsir, L. Binda, C. Bläuer, J. Elsen, E. Hansen, R. VanHees, F. Henriques, E.E. Toumbakari, T. VonKonow, J.E. Lindqvist, P. Maurenbrecher, B. Middendorf, I. Papayanni, S. Simon, M. Subercaseaux, C. Tedeschi, M. Thompson, J. Valek, M.R. Valluzi, Y. Vanhellemont, R. Veiga, A. Waldum, RILEM TC203-RHM, Mater. Struct. 42 (2009) 853–865.
[88] M.R. Veiga, F. Carvalho, Argamassas de reboco para paredes de edificios antigos: requisitos e características a respeitar, Cadernos de Edificios 2 (2002) 39–55.
[89] E. Hansen, E. Doehne, J. Fidler, J. Larson, B. Martin, M. Matteini, C. Rodríguez, E. Sebastián, C. Price, A. Tagle, J.M. Teutonico, N. Weiss, A review of selected inorganic consolidants and protective treatments for porous calcareous materials, Rev. Conserv. 48 (2003) 13–25.

[90] M. Bouchar, Petrographical Study of Meroitic Mortars from an Amun Temple (el-Hassa), in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 55–63.
[91] M.C. Iglesias, G. Alonso, Ancient building requirements and the evaluation of different lime-cement mortars compositions, in APFAC (Eds.) 2°Congressso Nacional de Argamassas de Construção, APFAC, Lisboa, 2007, paper 81.07.
[92] A. Prado, M. Guerra, Manuales y normas. Revestimientos contínuos conglomerados, CSIC, Madrid, 1962.
[93] L. Sbordoni-Mora, Les matériaux des enduits traditionnels, in: VV.AA. Mortars, Cements and Grouts used in the Conservation of Historic Buildings, ICCROM, Rome, 1982, pp. 375–383.
[94] R. Mayer, Materiales y técnicas del arte, Hermann Blume, Madrid, 1933.
[95] M.J. Torre, Estudio de los materiales de construcción de La Alhambra, Ph.D.thesis, Universidad Granada, Granada, 1995.
[96] O. Cazalla, Morteros de cal. Aplicación al Patrimonio Histórico, Ph.D.thesis, Universidad Granada, España, 2002.
[97] M. Tavares, J. Aguiar, M.R. Veiga, Conservação e restauro de antigos revestimentos exteriores: caracterização de alguns casos, in: G.T. Argamassas (Ed.), Simpósio Brasileiro de Tecnologia das Argamassas, 2003, Paper 223.
[98] M. Stefanidou, I. Papayianni, The role of aggregates on the structure and properties of lime mortars, Cement Concrete Comp. 27 (2005) 914–919.
[99] B. İpekoğlu, H. Böke, Ö. Çizer, Assessment of material use in relation to climate in historical buildings, Build. Environ. 42 (2007) 970–978.
[100] I. Villaseñor, C. Price, Technology and decay of magnesian lime plasters: the sculptures of the funerary crypt of Palenque, Mexico, J. Archaeol. Sci. 35 (2008) 1030–1039.
[101] P. Faria, M. Tavares, M. Menezes, R. Veiga, G. Margalha, Traditional Portuguese techniques for application and maintenance of historic renders, in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 609–617.
[102] M. Fornés, Gurrea, Observaciones sobre la Practica del Arte de Edificar, M. Cabrerizo, Valencia, 1857.
[103] M. Pardo, Materiales de Construcción, M. Tello, Madrid, 1885.
[104] F. Nacente, El constructor moderno, Ignacio Monrós y Compañía, Barcelona, 1890.
[105] F. Renzo, Fresco, in: C. Maltese (Ed.), Las técnicas artísticas, Cátedra, Madrid, 1994, pp. 285–296.
[106] M. Fornés y Gurrea, Observaciones sobre la Práctica del Arte de Edificar, Cabrerizo, Valencia, 1841.
[107] M. Martínez, C. Gato, Tecnología de los oficios de la construcción, J. Nuevo, Madrid, 1930.
[108] M.E. Torrego, Textos de Historia del Arte de Plinio el Viejo, Visor, Madrid, 1988.
[109] C. DufourBozzo, La pintura mural antigua, in: C. Maltese (Ed.), Las técnicas artísticas, Cátedra, Madrid, 1994, pp. 279–285.
[110] C. Genestar, C. Pons, C.A. Mas, Analytical characterisation of ancient mortars from the archaeological Roman city of Pollentia (Balearic Islands, Spain), Anal. Chim. Acta 557 (2006) 373–379.
[111] DGA, Pliego de condiciones técnicas, Ministerio Vivienda, Madrid (1960).
[112] A. Bakolas, G. Biscontin, A. Moropoulou, E. Zendri, Characterization of structural byzantine mortars by thermogravimetric analysis, Thermochim. Acta 321 (1998) 151–160.
[113] B. Schouenborg, J.E. Lindqvist, H. Sandström, M. Sandström, K. Sandin, E. Sidmar, Analysis of Old Lime Plaster and Mortar from Southern, SP Technical Research Institute Sweden, Borås, 1993.
[114] P. Cataneo, I Quattro primi libri di architettura, Gregg Press, Holand, 1964.
[115] J. Villanueva, Arte de Albañilería ó Instrucciones para los jóvenes que se dediquen á él, Don Francisco Martínez Dávila, Madrid, 1827.
[116] C.A. Jombert, Architecture modern ou l'art de bien bâtir pour toutes sortes de personnes tant pour les maisons des particuliers que pour les palais, Minkoff Reprint, Paris, 1728.
[117] I. Maxwell (Ed.), Proceedings: Cost Action C5, Historic Scotland, Edinburgh, 2000.
[118] K. Van Balen, B. Bicer-Simsir, L. Binda, C. Bläuer, J. Elsen, C. Groot, E. Hansen, R. Van Hees, F. Henriques, J. Hughes, E.E. Toumbakari, T. Von Konow, J.E. Lindqvist, P. Maurenbrecher, B. Middendorf, I. Papayianni, S. Simon, M. Stefanidou, M. Subercaseaux, C. Tedeschi, M. Thomson, J. Válek, M.R. Valluzi, Y. Vanhellemont, R. Veiga, The role of mortar in masonry: an introduction to requirements for the design of repair mortars, in: J. Válek, J.C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 1323–1329.
[119] Ministerio Vivienda, Revestimientos de Paramentos. Enfoscados, NTE-RPE, Publicaciones, Madrid, 1974.
[120] R. Marcos, Bausá, Manual del Albañil, Dirección y Administración, Madrid, 1879.
[121] M.D. Robador, El sentimiento en la antigua construcción, Informes Construcción 502 (2006) 17–32.
[122] B. Megna, G. Rizzo, L. Ercoli, Mortars and plasters under the mosaics and the wall paintings of the Roman Villa at Piazza Armerina, in: J. Válek, C. Groot, J.J. Hughes (Eds.), Proceedings 2nd HMC, RILEM, France, 2010, pp. 275–283.
[123] M. Myrin, K. Balksten, Lime based repair mortars–influence by surface working methods on behavior and durability of mortar, in: R. Fort, M. Álvarez-de-Buergo, M. Gómez-Heras, C. Calvo-Vázquez (Eds.), Heritage, weathering and conservation, Taylor & Francis, London, 2006, pp. 763–769.