Journal of Management and Sustainability; Vol. 13, No. 2; 2023
ISSN 1925-4725 E-ISSN 1925-4733
Published by Canadian Center of Science and Education

Proposal Mixes Process Method for Masonry Structure Laying Mortar

White José dos Santos[1], Maria Teresa Gomes Barbosa[2], Vinicius Martins Galil[2], Edgar Vladimiro Mantilla Carrasco[3], Marco Antônio Penido de Rezende[3], Rejane Costa Alves[4] & Eliene Pires Carvalho[5]

[1] Federal University of Minas Gerais, Engineering school, Belo Horizonte, MG, Brazil

[2] Federal University of Juiz de Fora, Department of Civil Construction, Juiz de Fora, MG, Brazil

[3] Federal University of Minas Gerais, School of Architecture, Belo Horizonte, MG, Brazil

[4] Federal University of Espírito Santos, Department of Forest and Wood Sciences, Vitória, ES, Brazil

[5] Federal Center for Technological Education of Minas Gerais, Belo Horizonte, MG, Brazil

Correspondence: Department Civil Construction, Federal University of Juiz de Fora, Juiz de Fora, Brazil or Department of Materials Engineering and Construction, Federal University of Minas Gerais, Belo Horizonte, Brazil.

Received: September 20, 2023 Accepted: November 10, 2023 Online Published: November 23, 2023

doi:10.5539/jms.v13n2p169 URL: https://doi.org/10.5539/jms.v13n2p169

Abstract

This paper presents an experimental method that procedures high-strength mortars to do with laying structural masonry found on the required properties and conditions of use. Literature research reviews were carried out that developed into the mix proportioning experimental process applied for mortar for laying structural masonry. Compressive strength tests, flexural strength tests, and digital microscope analysis were done to validate the methodology. The experimental program used Portland cement, hydrated lime, and natural quartzose sand. The research results mix all materials in a suitable proportion that shows in graphics with high assurance, i.e., 95%. Finally, it is possible to conclude that the process was efficient and provided high-quality masonry laying mortar about the existing environmental conditions.

Keywords: mix procedure, materials proportion, construction properties, laying mortar

1. Introduction

Mortars are used extensively throughout the world in applications such as wall and ceiling coatings, flooring, or grouting, and even for structural purposes, such as masonry and precast mortar grout (Santos, 2011; Barbosa et al., 2021; Castro et al., 2021; Schuab et al., 2021). In recent years, several companies have been replacing pre-prepared for precast mortars due to the difficulties in stocking and characterizing materials and inaccurate material proportions at the construction site (Barbosa, Santos, 2011; Haddad et al., 2020; Souza, Carvalhais, Santos, 2021).

Furthermore, it is significant to consider the inaccuracies found in various current procedures, which can be very specific to regions or material types. Current procedures include seeking the optimal content of binder (clay, phyllites, or lime powder) (Selmo, 1989) for general conditions, without regard to the relationship between the binder and moisture or complying with specific requirements such as the use in building façades (Selmo & Helene, 1991); the binder based on the specific clays available in a particular region (Gomes & Neves, 2002); proportion materials mortars from the maximum consumption of fines, using equations and tables that often do not represent the reality of material in a particular region; proportion materials through adjustments based on particle packing concepts, granulometric curves for sand (Lara et al., 1995); and proportioning through mathematical modeling by SIMPLEX, i.e., network statistical applications (Bahiense et al., 2008; Destefani & Holanda, 2009; Souza et al., 2020a; Souza et al., 2020b).

Masonry laying mortars, especially in structural applications, must have the main features: deformation suitable for different types of environments/conditions; support/bond to the bricks; withstand the acting loads without cracking or rupturing; additional acoustic and thermal insulation systems; compressive strength adequated, flexural strength and aggressiveness agent strength present in cleaning materials (exposed bricks), among others (Schneemayer et al., 2014; Haach et al., 2014; Sanchez, 2013; Carloni & Subramanian, 2012; Harajili et al., 2010; Gorokhovich et al., 2010; Martinelli, 1989).

The mortar performance is subject to its roughness, which is set by the sand particle size (Sahmaran et al., 2009; Lange et al., 1997; Meng et al., 2012; Goble & Cohen, 1999; Peng & Ding, 2009); the final finishing (Faria et al., 2015; Sanchez, 2013); mechanical strength (related to materials) (Pan & Weng, 2012; Peng & Ding, 2009; Kadri & Duval, 2002; Sahmaran et al., 2009), efficient mix procedure forms (Silva, 2006; Allwood & Ashby, 2011; Haddad et al., 2020; Souza, Carvalhais, & Santos, 2021) and the water/cement factor (Motta & Oliveira, 2013; Souza, Carvalhais, & Santos, 2021).

This research aims to develop an experimental mix procedure process for structural masonry laying mortar based on local requirements (workability and mechanical properties) and material characteristics. Santos et al. (2018), our research group, developed a mixing process (described hereafter) that demonstrated its feasibility for proportioning mixed coating mortars. The research highlight is process application (method) for materials proportions for laying mortars for structural masonry because most methods set a lower or upper limit for it. In this research, upper and lower limits are obtained. This result is typical of structural masonry, in which the mortar needs to be between 70-100 % of the strength of the brick.

2. Mix Procedure Process

This method seeks to establish the material's optimum proportions for the mortar mixture where the concepts and appropriate technical and scientific properties depend on the use and materials characteristics.

The simple implementation process was used for high efficiency who used software available to building professionals, such as spreadsheets. Santos et al. (2018) minimized mistakes from errors in mixtures at the application sites and produced structural masonry laying mortar of higher quality and durability through adjustments made to the method.

2.1 Conditional Parameters

Materials properties database

- Specific mass of all materials.
- Granulometry curve, maximum diameter, fineness modulus, and pulverulent material content of the aggregates (sand).
- Environmental conditions site, strength mortar, and durability requirements.
- Standardization that must comply.
- If the laboratory mixture mortar, it is necessary to simulate the site conditions before the mortar is used at the construction site.
- If the proportion of materials process is carried out at the construction site, at the very least, the appropriate equipment and skilled labor are required.

2.2 Mix Proportion Procedure

The mix procedure method is a sequential activity that allows the professional to obtain a proportion of materials, develop experimental tests, and define the most suitable mix proportion mixture for a particular purpose. There are 7 (seven) steps to be performed that allowing to obtain the materials proportion required, such as:

Step 1. The aggregate amount in the mixture is obtained Equation (1) that the aggregate void coefficient is considered:

$$C_{sand}=100-\left[\left(1-\frac{\gamma_u}{\gamma_r}\right).100\right] \quad (1)$$

Where: C_{sand} = fine aggregate content in the mixture, in %;

γ_u = Specific unit mass of fine aggregate in g/cm³;

γ_r = Specific mass of fine aggregate in g/cm³.

C_{voids} = void coefficient, in %.

V_s = volume of solids in liters.

V_t = total volume in liters.

V_v = volume of voids in liters.

Step 2. The water/cement ratio of the mixture was determined experimentally, being initially 15%.

Step 3. The binder amount in the mixture was determined. Table 1 shows the expression which is based on Equation 1 and the minimum consumption of the binder.

Step 4. Experimentally adjust the basic mixtures (Table 1): verify the consistency and, if necessary, confirm the amount of water and other materials in the mixture. The following must be observed:

- Exudation and/or lack of cohesion of the material. It may be an indication that the amount of binder is insufficient, i.e., to increase the binder in the mixture or adjust the aggregate with the addition of fines.
- High cohesion, i.e., the mortar adheres to the trowel, even when wet. In this case, it is acceptable to add coarser sand and/or decrease the amount of finer sand.
- Mortar is very rough. It is an indication that the grain size of the sand particles is large. In the case of masonry laying mortar, the relationship between the maximum aggregate size and thickness of the gasket should be checked to ensure that it does not exceed ½. If this value is exceeded, the material should be screened, any undesirable material should be removed, and the dosing procedure should be remade.
- It is possible to control the insertion of any additions/additives to make the mortar denser and more strength or incorporate more air to make the mixture more expansive. It is important to indicate any plasticizers or other additives (super and hyper) or additions (silica fume or metakaolin) to obtain high-strength mortar.

Table 1. The binder content for different performance

Extreme points					
Designation	Ciment (%)	Lime (%)	Sand (%)	Water (%)	Total (%)
Mixture 1	5	Z	C_{sand}	15%	100%
Mixture 2	(Z + 5) / 2	(Z + 5) / 2	C_{sand}	15%	100%
Mixture 3	Z	5	C_{sand}	15%	100%
Nearby points - higher strength					
Designation	Ciment (%)	Lime (%)	Sand (%)	Water (%)	Total (%)
Mixture 1	(Z + 5) / 2	(Z + 5) / 2	C_{sand}	15%	100%
Mixture 2	(3Z + 5) / 4	(Z + 15) / 4	C_{sand}	15%	100%
Mixture 3	Z	5	C_{sand}	15%	100%
Nearby points - less strength					
Designation	Ciment (%)	Lime (%)	Sand (%)	Water (%)	Total (%)
Mixture 1	(Z + 5) / 2	(Z + 5) / 2	C_{sand}	15%	100%
Mixture 2	(3Z + 5) / 4	(Z + 15) / 4	C_{sand}	15%	100%
Mixture 3	Z	5	C_{sand}	15%	100%

Note. * Adopting Z = 100 - C_{sand} - 5 -15.

Step 5. Mortar properties: the main elements are as follows:

- In the fresh state: consistency, cohesion, and water retention, which will ensure the workability required during the application process.
- In the hardened state: due to compressive strength and flexural strength, indicating the bearing capacity of the material.

Step 6. The ideal proportions in the mixed procedure mixture: define the most suitable mixture for the conditions of use that also follows the material parameters. These are works like mixed design characteristics that correspond to the specified value associated with a confidence interval, which can be unilateral or bilateral, according to Equation 2.

$$F_d = F_k \pm t_{\frac{\alpha}{z}n-1} .s \tag{2}$$

Where: F_d: mix design limit of a certain property of the mortar.

F_k: characteristic limit of a certain property of the mortar.

$t_{\frac{\alpha}{z}n-1}$: Tabulated value (t Distribution) for a significance level of 5% (95% reliability) and degree of freedom (n-1).

s: is the sample standard deviation estimated by linear regression of ownership (vertical axis - y) and the constituents of the materials in a percentage of volume (x-axis - x);

n: number of samples.

The mixture choice can be made in the following ways:

- Graphs: obtaining the right mixture consists of graphs that correlate the properties with mixture constituents from defined limits.
- Analysis of mathematical equations: where the ideal mixtures are obtained from the approximation equations given by the trend lines from the correlation graphs between each property and the percentage of materials.

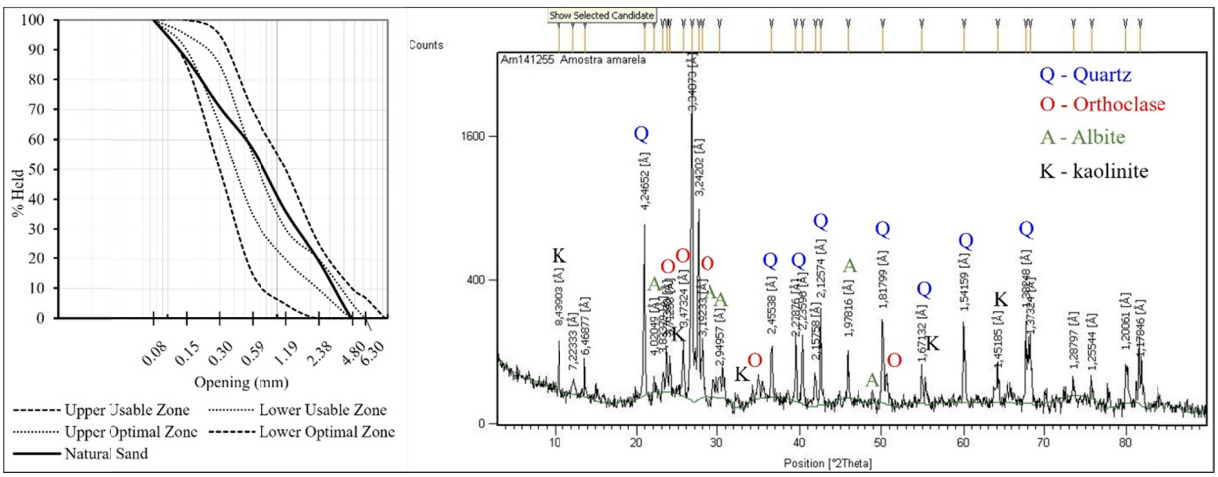
Step 7. Method conclusion: verify the appropriate mixture by performing small-scale tests that check the amount of water in the mixture through a consistency test. It is then necessary to verify the required properties before the mortar is to be used at the worksite. The process ends with the ideal mixture presentation, in the requested versions (mass, volume, percentage, per cubic meter, per sack of cement).

3. Experimental Procedure

Portland cement type CP II-E-32 manufactured by HOLCIM do Brasil SA (specific mass and unit mass were 3.1 kg/l and 1.70 kg/l, respectively); Hydrated lime Special type CH I - MASSICAL manufactured by ICAL Ltda (specific mass and unit mass were 2.8 kg/l and 0.50 kg/l); and natural quartzose aggregate in upper useable area - were used (see Table 2 and Figures 1 and 2).

Table 2. Physical characteristics of natural aggregate

Maximum diameter	2.4 mm
Fineness modulus	3.11
Real density	2.577 kg/dm³
Loose true density	1.439 kg/dm³
Compact unit density	1.581 kg/dm³
Clay content	Exempt
Content material powder	2.68%
Organic impurity	<300p.p.m.
Water absorption	2.17%
Forms of Grains	Rounded



(a) (b)

Figure 1. Characterization of aggregate (a) Granulometric curve and (b) X-Ray Diffraction (XRD) - quartz (major); orthoclase (medium-low); albite (bass); kaolinite (bass).

The experimental program of this study was to characterize the materials (ABNT, 2001a, 2001b, 2003, 2006, 2010); and conduct necessary tests to validate the mortar mix design method for masonry laying. Consistency tests, compression tests, and tension tests in bending were evaluated under laboratory conditions, with the objective being to identify a mixture that would meet resistance conditions within a bilateral confidence interval.

Compressive and flexural strength tests were carried out at 7, 14, and 28 days on 4x4x16 cm (6 samples each) test samples in a CONTENCO press with load application of 0.5 MPa/s and precision of 10 N, according to NBR 13279 (ABNT, 2005). A 1000x digital microscope was also used to analyze images of the surface of mortars and investigate the interaction between the matrix content (cement and lime) and aggregates in these composites.

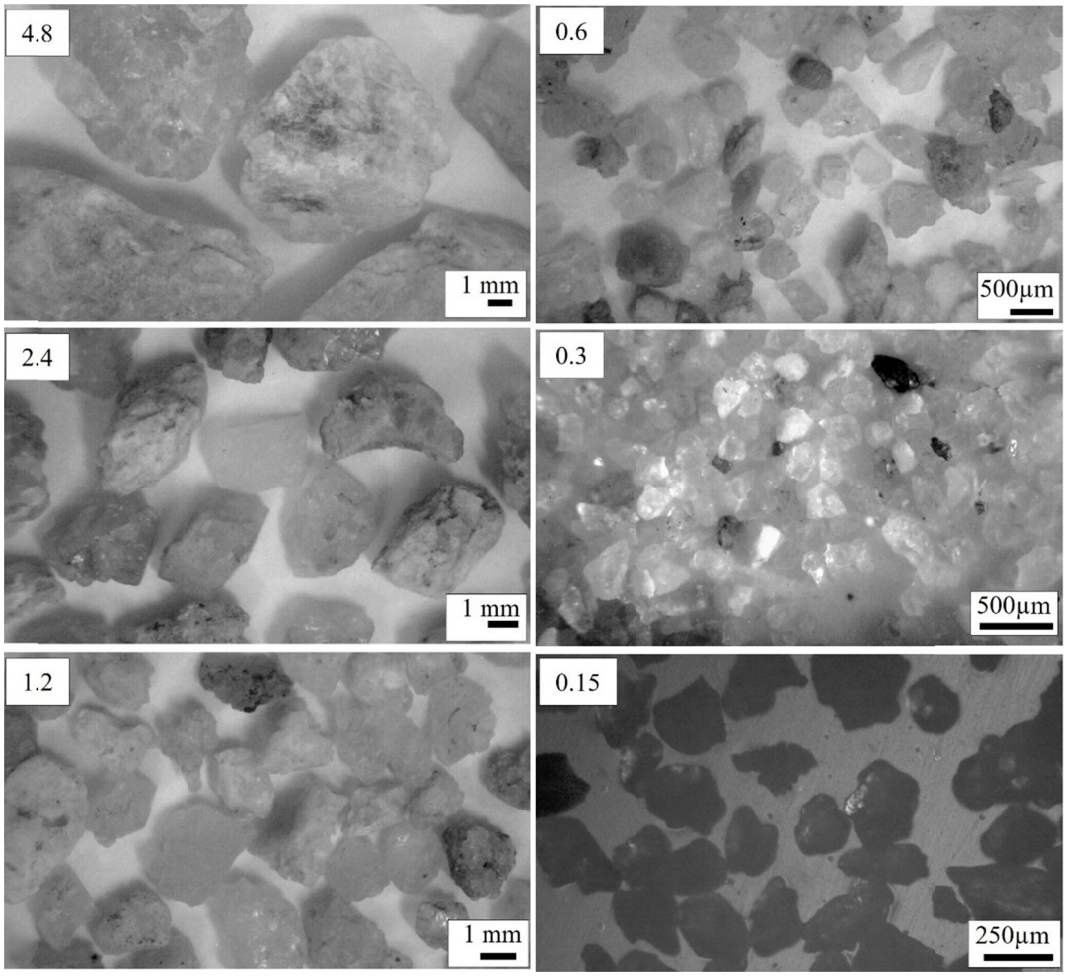


Figure 2. Aggregate stereoscopic microscope and optical microscope images

4. Results and Discussion.

4.1 Material Parameters

The materials described in item 3.1 were used.

The research mortar used for laying structural masonry laying follows standardization (ABNT NBR 15961, 2011) as follows: the compressive strength should be around 70% of the brick's strength. A brick, in this work, has an fbk equal a 16 MPa (brick compressive strength) soon mortar compressive strength is equal to 11.2 MPa. The mortar simulation condition was an average value associated with a bilateral confidence interval for an established age. This proceeding allows mortars for different conditions and estimation of the minimum or maximum values, as follows:

- Sand: Table 2 shows specific mass and specific mass units (2.577 kg/l and 1.581 kg/l, respectively). Equation (1) results in a sand consumption of 61.45%; therefore, the binder aggregate mortar ratio is 40% (or about 1/3), it is a good result because binder upper consumption is positive since this mortar type needs greater compressive strength (Santos et al., 2018). In addition, the mortar fresh state properties are profitable with aggregate and cement fines, supporting workability and cohesion.
- Water/cement ratio: cement mortars require greater strength and cohesion; therefore, we decided to use a lower

water/cement ratio, to 14% at the beginning of the calculation, which is a higher consumption of cement than adequate because the maximum diameter and fineness modulus sand are 2.4 mm and 3.11, respectively.

- Binder: the ideal mix design in the mixture adopted a process of approximation points that mid-point to stronger mixtures (higher cement consumption - see Table 2). The specific mass and unit mass were 3.1 kg/l and 1.70 kg/l for cement, 2.8 kg/l, and 0.50 kg/l for lime, respectively. The data were provided by the manufacturers.
- Mix proportions: the workability adopted was 260±10 mm. The mortar mixtures showed great cohesion that was suitable for use (Monhamadian, 2013) but, some corrections were made due to workability, see Table 3. Despite mixture corrections, the binder/aggregate ratio (by volume) was constant at 0.40. For workability, it was necessary to increase the water/dry materials ratio from 0.16 to 0.18, i.e., 11%.

Table 3. Structural masonry laying mortar proportions

	Unit	Ciment	Lime	Sand	Water
1st Mixture	(kg)	1.000	0.462	5.962	0.988
	(l)	1.000	1.571	6.433	1.680
	(%)	9.36	14.70	60.21	15.72
2nd Mixture	(kg)	1.000	0.202	3.913	0.688
	(l)	1,000	0.687	4.222	1.170
	(%)	14.13	9.70	59.65	16.52
3rd Mixture	(kg)	1.000	0.129	3.340	0.533
	(l)	1.000	0.439	3.604	0.906
	(%)	16.81	7.37	60.58	15.23

4.2 Optimum Proportion

The age of 14 days was chosen to evaluate the dosage, as this is a reasonable period for practice in works and laboratories and is an age in which the strength of the laying mortar tends to reach values close to the maximum.

The 14 days of age is a reasonable period for construction sites and laboratories because compressive strength is near 90% last compressive strength, i.e., 28 days of age. The ANOVA tool shows linear regression, see Figure 3, with a reliability of 95%. Therefore, it is possible to find values for compression strength (f_c)) between 9.991 MPa and 12.409 MPa. These mortar mixtures are shown in Table 4 and Figures 3 and 5. The yellow area is the ratio of materials limits for specified properties.

Table 4. Compression (f_c) and flexural (f_t) strength results

	f_c (MPa)	Error - f_c (MPa)	f_t (MPa)	Error - f_t (MPa)
1st Mixture	5.06	0.07	1.563	0.100
2nd Mixture	13.80	0.45	3.008	0.118
3rd Mixture	14.85	0.15	3.547	0.049

Figure 4 shows a correlation between Flexural strength and Compressive strength, according to the results found for each mixture. The yellow area, see Figure 5, is the ratio of materials limits, i.e., between 1.754 MPa and 2.465 MPa.

Through the graphs (Figures 3 and 5) performed approach research the three dosage mixtures through polynomial curves to the 2nd degree, which R^2 equals 1. These equations are valid for these research materials, conditions, and in the range evaluated in each property. Finally, the most suitable proportion materials were defined for materials, conditions, and mechanical properties (minimum and maximum limits).

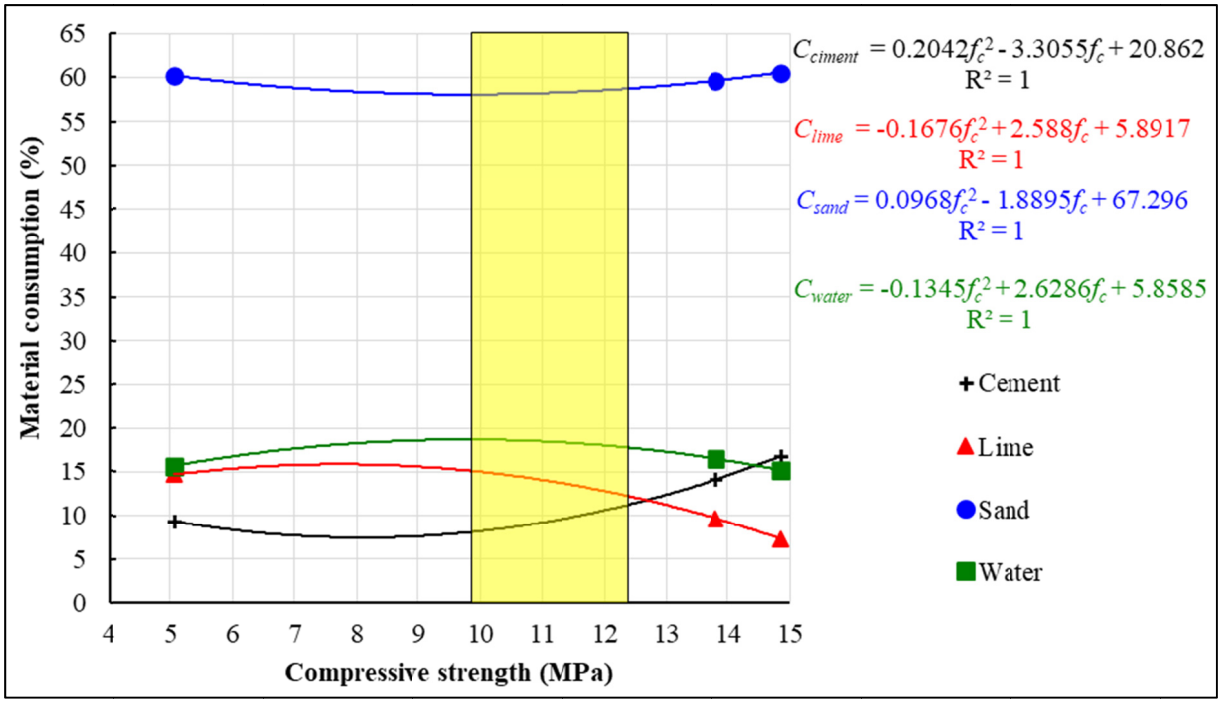


Figure 3. Materials consumption x compressive strength in function of (f_c) - 14 days.

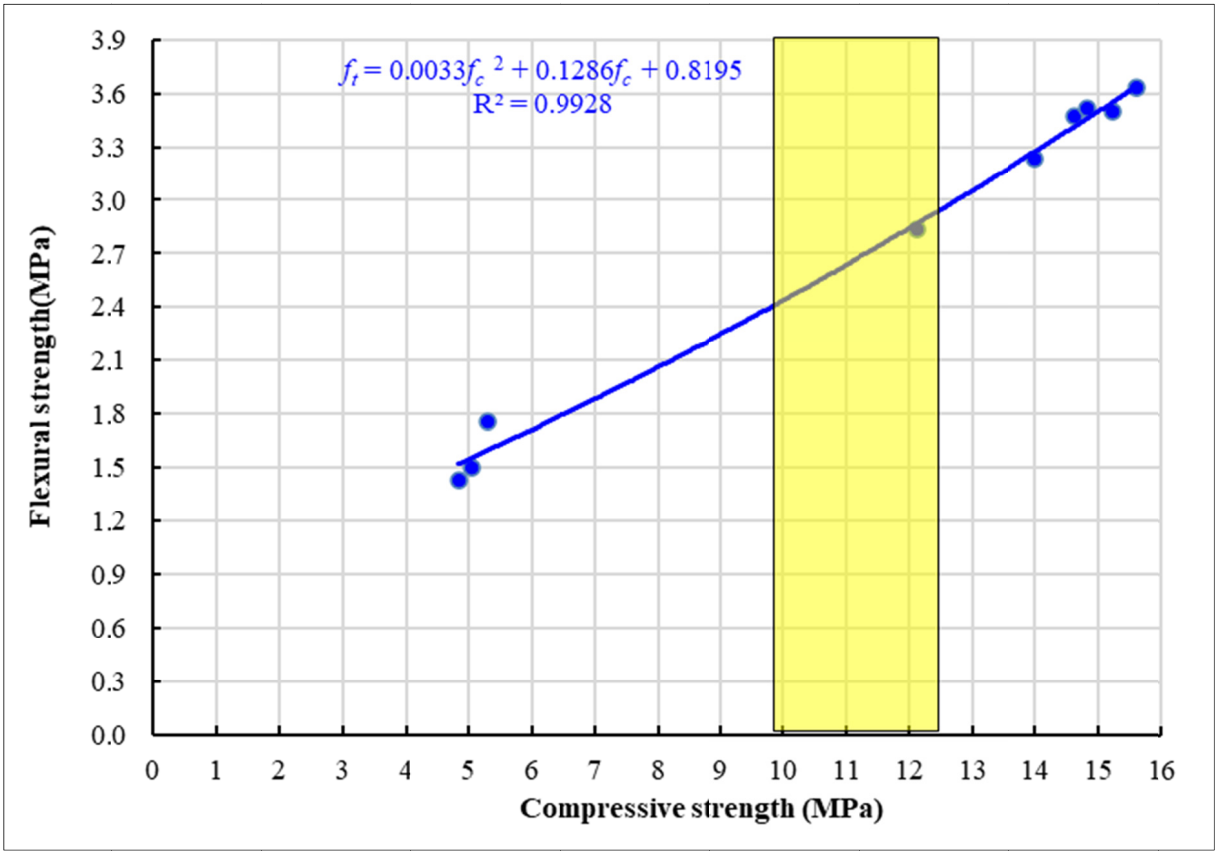


Figure 4. Flexural strength (f_t) x Compressive strength (f_c) ratio - 14 days

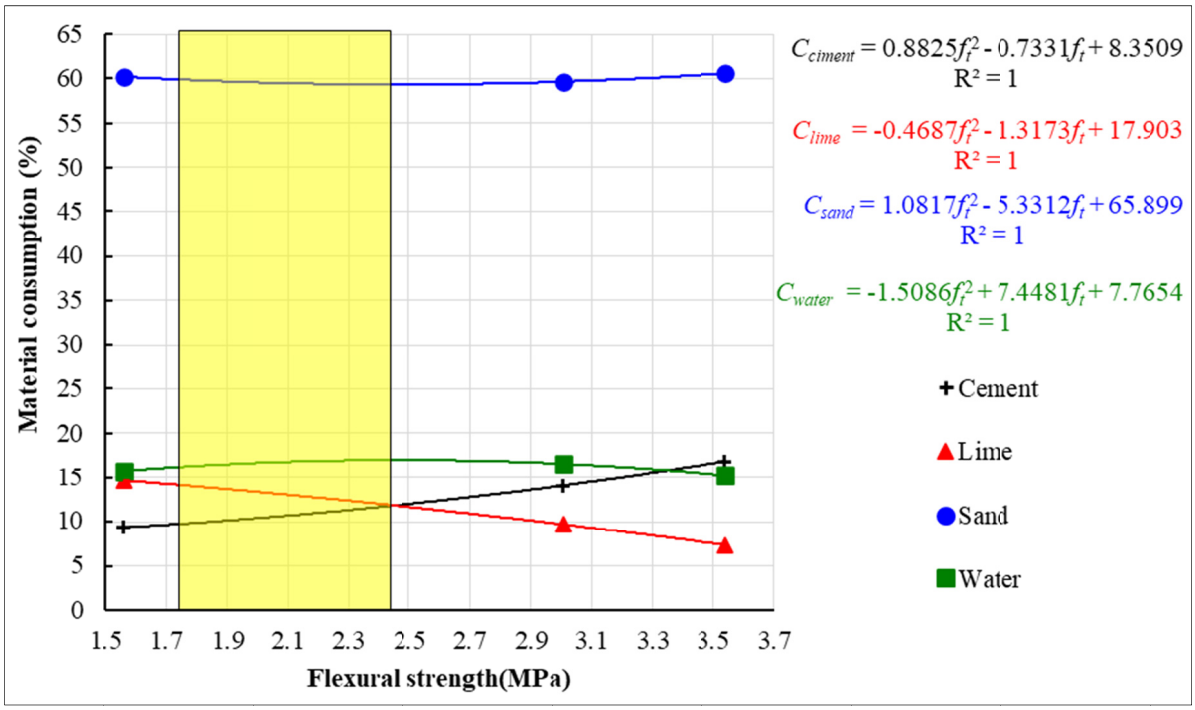


Figure 5. Materials consumption x flexural strength (f_t) - 14 days

After that, specimen tests (ST) were made with the mortar for the validation of the results, 36 ST for compressive strength and 18 ST for flexural strength. The results can be seen in Table 5 and Figures 6 and 7. Analyzing the results, the procedure is feasible and efficient, within the given parameters and conditions, and a spreadsheet proved to be a very interesting alternative because it maximized the amplitude use of this method.

Moreover, it can be noted that the proposed procedures demonstrate how the constituents interfere with the composite's properties, in either the fresh or hardened state.

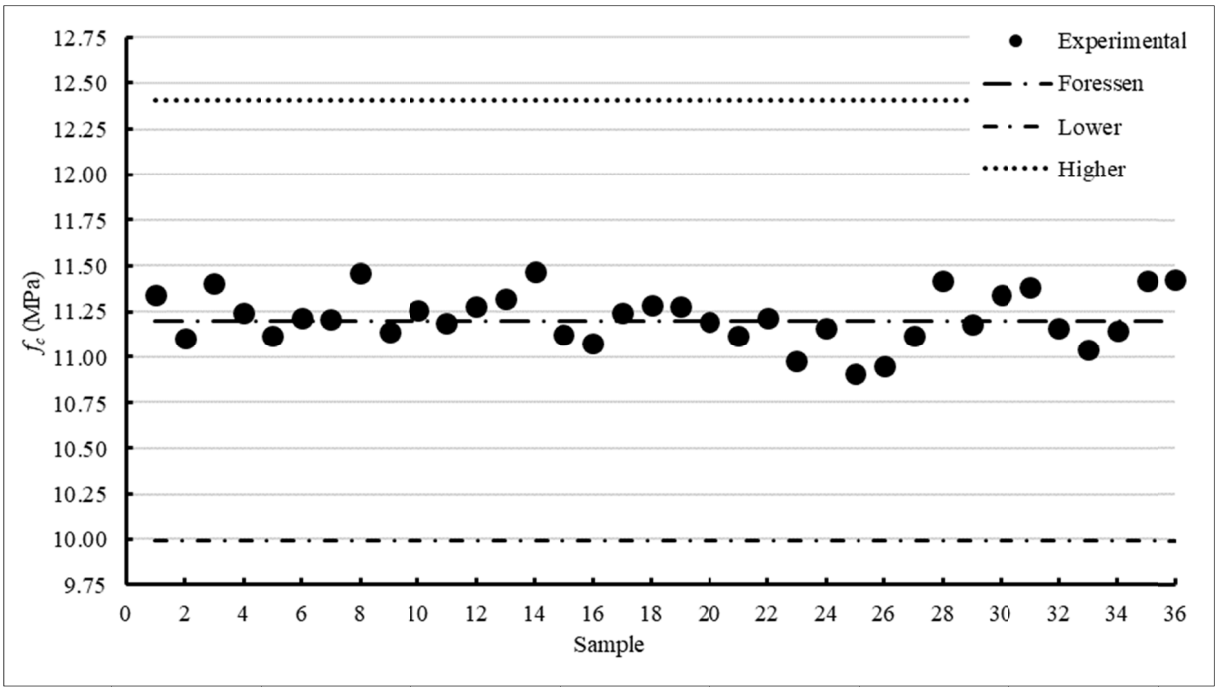


Figure 6. Compressive strength (f_c) at 14 days for the ideal mixture

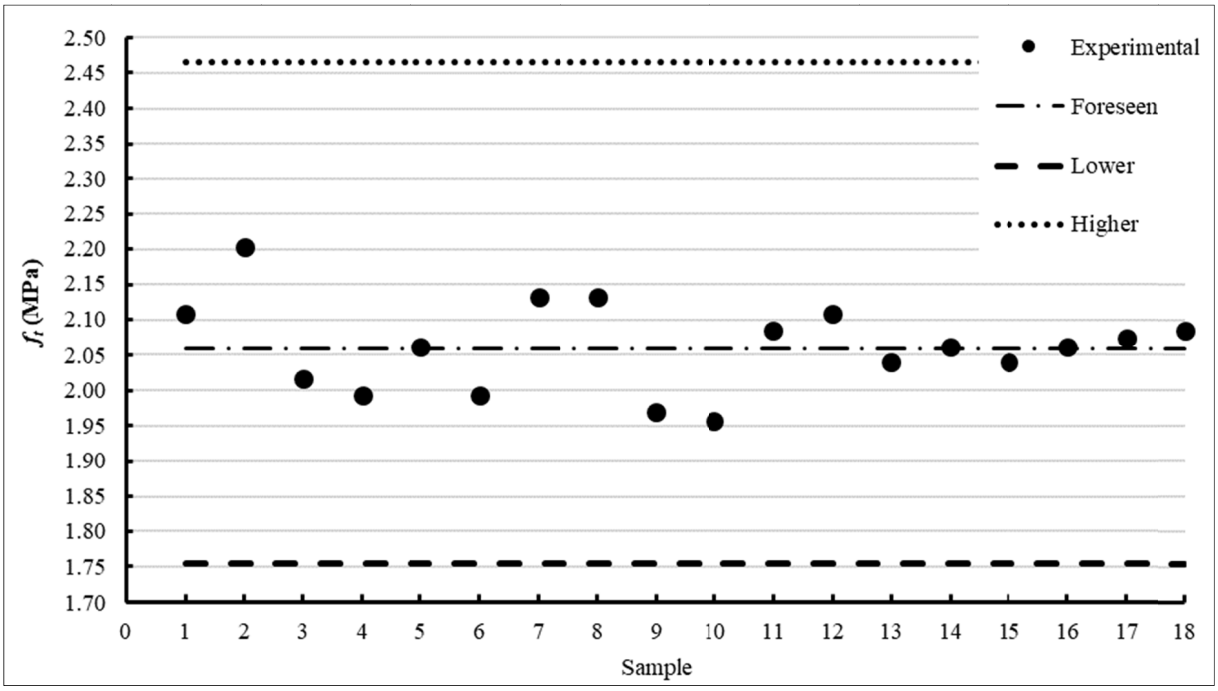


Figure 7. Flexural strength (f_t) at 14 days for the ideal mixture

Table 5. Results from compression (f_c) and flexural (f_t) strength for proportion of structural masonry laying mortar

f_c (MPa)	Error - f_c (MPa)	f_t (MPa)	Error - f_t (MPa)
11,22	0.02	2.063	0.063

4.3 Evaluation of the Mix Design Mixtures at Different Ages

Figure 8 and Table 6 show the results of the compression strength test for three basic masonry laying mortar mixtures. It appears that the logarithmic approach and potential were the most appropriate, allowing estimation/interpolation of the values for Compressive strength at different ages. Little variation in the mixtures over the analysis period was recorded. We noticed that after 7 days approximately 75% of the ultimate strength was obtained.

Table 6. Compressive strength results at different ages in masonry laying mortar

Mixture	Age (days)	f_c (MPa)	Error (MPa)	Increase (%)
1st Mixture	7	4.05	0.36	
	14	5.06	0.07	24.96
	28	5.56	0.06	9.85
2nd Mixture	7	11.33	0.18	
	14	13.80	0.45	21.76
	28	13.88	0.21	0.57
3rd Mixture	7	3.14	0.63	
	14	14.85	0.15	13.01
	28	14.90	0.14	0.33

Note. * Percentage increase between 7 days and 14 days. ** Percentage increase between 14 days and 28 days.

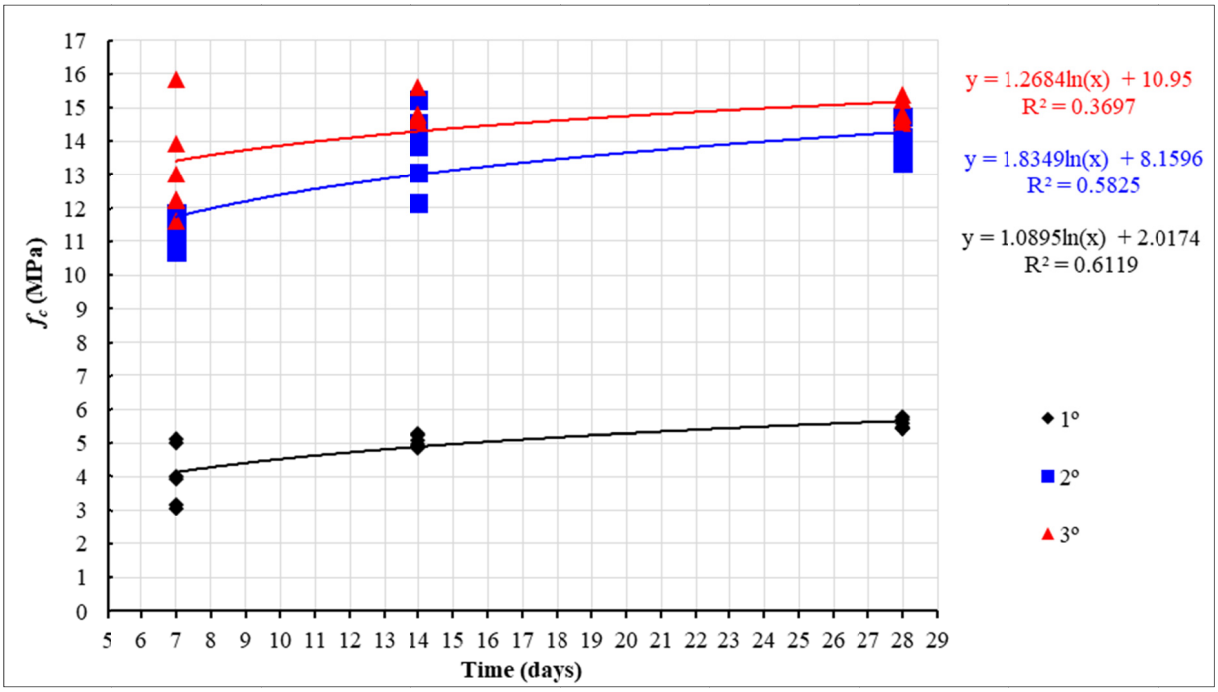


Figure 8. Compressive strength (f_c)results over ages for masonry laying mortar

These mixtures are higher in cement than in lime, soon compressive strength is smaller after 14 days. For the significance of correlations between compressive strength and curing time, an ANOVA test was performed, whereby it was found that the variations are significant, see Figures 7 and 8. A similar conclusion is flexural strength (see Table 7 and Figure 9).

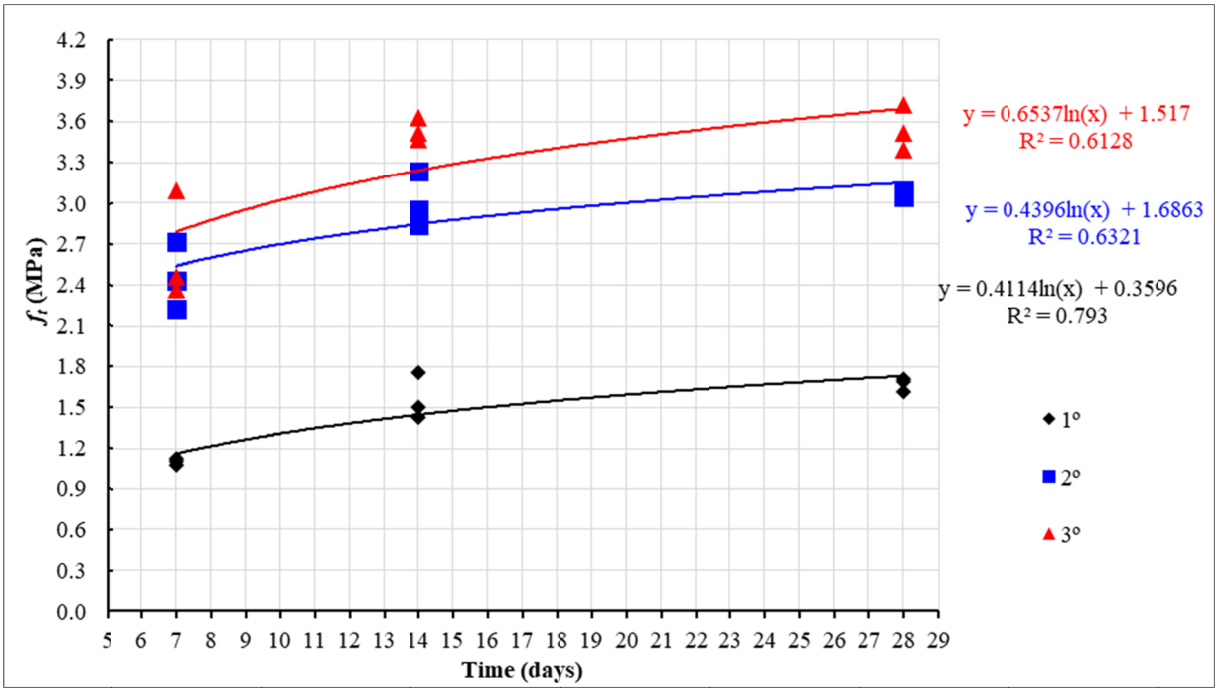


Figure 9. Flexural strength (f_t)in bending results over ages for masonry laying mortar

Table 7. Flexural strength in bending results at different ages in masonry laying mortar

Mixture	Age (days)	f_t (MPa)	Error (MPa)	Increase (%)
1º Mixture	7	1.10	0.01	
	14	1.56	0.10	41.84
	28	1.67	0.03	7.00
2º Mixture	7	2.46	0.14	
	14	3.01	0.12	22.22
	28	3.07	0.01	2.08
3º Mixture	7	2.64	0.23	
	14	3.54	0.05	34.02
	28	3.55	0.10	0.22

Note. * Percentage increase between 7 days and 14 days. ** Percentage increase between 14 days and 28 days.

4.4 Microstructural Analyses

Figures 10 (a), (b), (c), and (d) show digital microscope images of the three basic mixtures and of the ideal mixture for the masonry laying mortar. Several pores that had joined together to create megapores (> 7,5µm - IUPAC) were observed, in addition to varying pore sizes which were composed of many individual pores converging to give a more durable mortar.

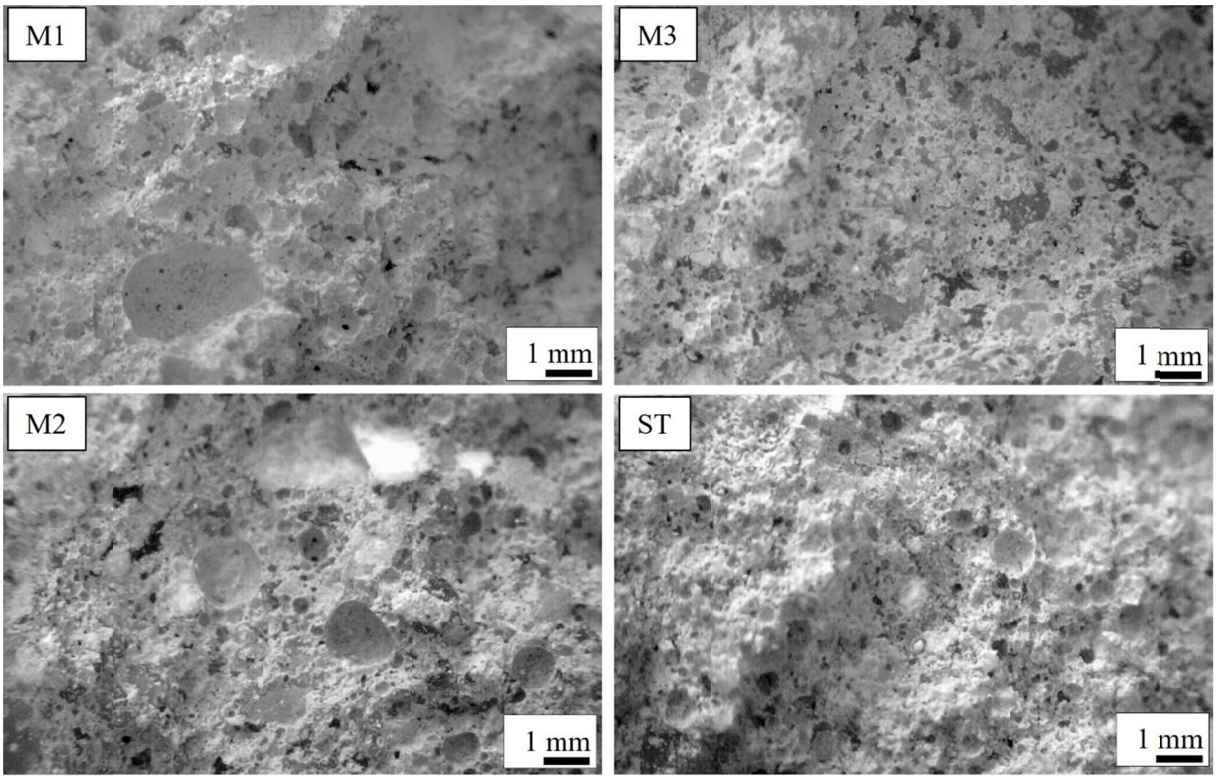


Figure 10. Microscope image: (M1) Mixture 1; (M2) Mixture 2; (M3) Mixture 3 and (ST) sustainable mixture of mortar for masonry structural laying

Figure 10 corroborates with the data obtained previously in which a sample with many pores, but with distance between them. These pores help the masonry laying mortar to withstand small deformations without cracking. We notice that the increase in the lime content generated very small pores and tends to weaken the matrix and isolated distribution of these pores allows the carbonation of lime, which can increase strength and thus long-term durability. The aggregate contributed to an increase in the number of pores of larger size (greater than 200 µm) and with an irregular shape, caused by the arrangement of the grains in the matrix, being the lack of binder responsible for not filling the voids left by the aggregate. As for cement, very high values generate very rigid materials, which

makes it difficult for any deformation of the elements to accommodate. Moreover, this excess binder tends to create higher retraction, causing several cracks and a reduction of the resistance capacity of the masonry. The amount and size of pores tend to decrease with increasing amounts of cement, as predicted in the bibliography (Souza et al., 2020a). Given the above, it appears that the sustainable mixture was closer to the 3rd mixture than the one with fewer pores, and these were more widely spaced and, therefore more strength and durable.

5. Conclusions

The results and images allowed confirmation and interaction between the concepts and knowledge covered, proving the feasibility of the proposed procedures and techniques. However, above all, the results allow the expansion of knowledge about masonry laying mortar, especially regarding the dosing process, the influence of the constituents in this cementitious composite, and the correlations and interdependencies that exist between these properties.

We concluded that the proposed method is efficient and achieves good quality mortar for use in structural masonry laying purposes while considering different environmental conditions. The proposed innovations, which are the means of acquiring the contents of each component and the adequate mixtures through approximation curves developed via spreadsheets, were adequate for use in factories, laboratories, and work sites.

Acknowledgments

The authors wish to thank the Brazilian agencies National Counsel of Technological, Research Support Foundation of Minas Gerais (FAPEMIG - project number APQ-00584-21), Scientific Development (CNPq - project number 304596/2022-1) and Coordination of Superior Level Staff Improvement (CAPES) and the Federal University of Juiz de Fora (UFJF).

References

Allwood, J., & Ashby, M, G. T. W. E. (2011). Material efficiency: a white paper. Resources. *J. Conservation and Recycling*, *55*(2011), 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002.

Bahiense, A. V., Manhães, R. T., Alexandre, J., Xavier, G. C., Monteiro, S. N., & Vieira C. M. F. (2008). Use of the experimental design in the incorporation of the ceramic waste in mortars for obtaining water retention capacity. *Cerâmica*, *54*(2008), 395–403. http://dx.doi.org/10.1590/S0366-69132008000400003.

Barbosa, M. T. G., & Santos, W. J. (2013). *ARGAD: High Performance Mortar*. Portugal SB13: Contribution of Sustetainable Building to Meet.

Barbosa, M. T. G., Santos, W. J., Ludwig, Z., Souza, N. L. D., Stephani, R., & Oliveira, L. F. C. (2021). Optical Fiber Waste Used as Reinforcement for Concrete with Recycled Marble Aggregate. *Journal of Management and Sustainability*, *11*, 49–63. https://doi.org/10.5539/jms.v11n1p49

Brazilian Association of Technical Standards (ABNT). NBR 13279. (2005). *Mortars applied on walls and ceilings - Determination of the flexural and the compressive strength in the hardened stage*. Rio de Janeiro.

Brazilian Association of Technical Standards, NBR 15961. (2011). *Structural masonry - Concrete blocks* (Part 1 and 2). Rio de Janeiro, Brazil.

Carloni, C., & Subramaniam, K. (2012). FRP-Masonry Debonding: Numerical and Experimental Study of the Role of Mortar Joints. *J. Compos. Constr.*, *16*(5), 581–589.

Castro, N. L. B., Almada, B. S., Fajardo, A. A., Oliveira, C. A. S., & Santos, W. J. (2021). Influence of Addition Contents of Iron Ore Tailings on Structural Mortar. *Journal of Management and Sustainability*, *11*, 74–87, https://doi.org/10.5539/jms.v11n1p74

Destefani, A. Z., & Holanda J. N. F. (2011). Use of simplex lattice experimental design in the study of ornamental rock waste as filler to obtain maximum compaction. *Cerâmica*, 57, 491–498, http://dx.doi.org/10.1590/S0366-69132011000400018.

Faria, P., Santos, T., & Aubert, J. (2015). Experimental Characterization of an Earth Eco-Efficient Plastering Mortar. *Journal of Materials in Civil Engineering*, *28*(2015) 1–9. https://doi.org/10.1061/(ASCE)MT.1943-5533.0001363.

Goble, C. F., & Cohen, M. D. (1999). Influence of aggregate surface area on mechanical properties of mortar. *ACI Materials Journal*, 657–662.

Gomes, A. O., & Neves, C. M. M. (2002). Proposal for a rational dosing method mortar containing clay. *Ambiente Construído Journal*, *2*(2), 19–30.

Gorokhovich, Y., Doocy, S., Voustianiouk, A., & Small, C. (2010). Assessment of Mortar and Brick Strength in Earthquake-Affected Structures in Peru Using a Schmidt Hammer. *J. Perform. Constr. Facil.*, *24*(6), 634–640.

Haach, V., Vasconcelos, G., & Lourenço, P. (2014). Assessment of Compressive Behavior of Con-crete Masonry Prisms Partially Filled by General Mortar. *J. of Materials in Civil Engineering*, *26*(10), 04014068.

Haddad, L. D. O., Neves, R. R., Oliveira, P. V., Carvalho Junior, A. N., & Santos, W. J. (2020). Influence of particle shape and size distribution on coating mortar properties. *Journal of Materials Research and Technology*, *9*, 9299–9314, https://doi.org/10.1016/j.jmrt.2020.06.068

Harajli, M., Elkhatib, H., & San-Jose, J. (2010). Static and Cyclic Out-of-Plane Response of Mason-ry Walls Strengthened Using Textile-Mortar System. *J. Mater. Civ. Eng.*, *22*(11), 1171–1180.

Kadri, H. E., & Duval, R. R. (2002). Effect of ultrafine particles on heat of hydration of cement mortars. *ACI Materials Journal*, 138–142.

Lange, F., Mortel, H., & Rudert, V. (1997). Dense packing of cement pastes and resulting conse-quences on mortar properties. *Cement and Concrete Research*, *27*(10), 1481–1488.

Lara, D., Nascimento, O., Macedo, A., Gallo, G., Pereira, L., & Poty, E. (1995). *Dosage of mortars* (pp. 63–72). Simpósio Brasileiro de Tecnologia das Argamassas, Goiania.

Martinelli, F. A. (1989). *Contribution to the study dosage of mixed mortars destined for laying and masonry coating* (p.79). Thesis (MS), Polytechnic School of the University of São Paulo. São Paulo, Brazil.

Meng, L., Lu, P., Li, S., Zhao, J., & Li, T. (2012). Shape and size effects on the packing density of binary spherocylinders. *Powder Technology*, *228*, 284–294.

Monhamadian, H. A. (2013). Water Extraction in Natural Hydraulic Lime Based Mortar. *Journal of Materials in Civil Engineering*, 810–816.

Mota, J. M. F., & Oliveira, R. A. (2013). *Reinforcement model with reinforced mortar with added pozzolan for resistant masonry* (pp. 1–10). Anais do 5º Congresso Brasileiro do Concreto.

Pan, H., & Weng, G. (2012). Investigation of the Age-Dependent Constitutive Relations of Mortar. *J. Eng. Mech.*, *138*(3), 297–306.

Peng, Y., Hu, S., & Ding, Q. (2009). Dense Packing Properties of Mineral Admixtures in Cementitious Material. *Particuology Science and Technology of Particles*, *7*, 399–402. https://doi.org/10.1016/j.partic.2009.06.003.

Sahmaran, M., Lachemi, M., Hossain, K. M. A., Ranade, R., & Li, V. C. (2009). Influence of Aggregates Type and Sinze on Ductility and Mechanical Properties of Engineered Cementitious Composites. *ACI Materials Journal*, March June, 308–316.

Sánchez, E. (2013). *New Brazilian Standardization for Structural Masonry* (Ed. Interciência, vol. 1).

Santos, W. J. (2011). *High performance mortar*. Dissertation (Master) in Ambiente Construído. Juiz de Fora. Minas Gerais. Brazil.

Santos, W. J., Alvarenga, R. C. S. S., Pedroti, L. G., Silva, R. C., Freire, A. S., Moraes, B. A., & Carvalho, C. C. (2018). Proposal for a mix design method for coating mortar with artificial crushing sand. *Ambiente Construído* (Online), *18*, 225–243, https://doi.org/10.1590/s1678-86212018000100218

Schneemayer, A., Schranz, C., Kolbitsch, A., & Tschegg, E. (2014). Fracture-Mechanical Properties of Mortar-to-Brick Interfaces. *Journal of Materials in Civil Engineering*, *26*(9).

Schuab, M. R., Santos, W. J., & Borges, P. H. (2021). On the development of MK/BFS alkali-activated materials as repair mortars: Performance under free and restrained shrinkage tests. *Construction and Building Materials*, *275*, 1–14, https://doi.org/10.1016/j.conbuildmat.2020.122109

Selmo, S. M. S. (1989). *Cement mortar dosage Portland and lime coating for external facades of buildings* (p. 227). Thesis (MS), Polytechnic School of the University of São Paulo. São Paulo. Brazil.

Selmo, S. M. S., & Helene, P. R. L. (1991). *Dosage of cement mortar and lime Portland to external fa-çade cladding of buildings* (p. 12). Technical Bulletin, Polytechnic School of the University of São Paulo. São Paulo, Brazil.

Silva, N. G. (2006). *Cement mortar coating, lime sand and crushed limestone* (p. 164). Dissertation (master's in civil engineering), Federal University of Paraná, Curitiba. Brazil.

Souza, A. T., Caldas, R. B., Ludvig, P., & Santos, W. J. (2020). The effects of mixture's components on the mechanical properties and durability indicators of mixed mortar using simplex network method. *Construction and Building Materials*, *249*, 118740. https://doi.org/10.1016/j.conbuildmat.2020.118740

Souza, A. T., Carvalhais, C. A., & Santos, W. J. (2020). Analysis of chemical admixtures combination on coating mortar using Simplex network method. *Construction and Building Materials*, *239*, 117796, https://doi.org/10.1016/j.conbuildmat.2019.117796

Souza, A. T., Carvalhais, C. A., & Santos, W. J. (2021). Analysis of mortar coating with different types and proportions of chemical admixtures that have water retentivity properties. *IBRACON Structures and Materials Journal*, *14*, 1–16. https://doi.org/10.1590/S1983-41952021000600002