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**Análisis comparativo de las propiedades mecánicas de muros de albañilería
construidos con mortero convencional y mortero seco premezclado**

**TRABAJO DE INVESTIGACIÓN PARA OPTAR EL GRADO ACADÉMICO DE
BACHILLER EN INGENIERÍA CIVIL AMBIENTAL**

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Resumen

En este artículo se presenta el análisis comparativo entre 2 tipos de morteros, uno elaborado tradicionalmente y uno predosificado en seco. Se pretende conocer si el mortero predosificado ofrece ventajas ante el mortero elaborado tradicionalmente ya que este último en general, se elabora en condiciones poco controladas. Para ello, se evaluaron aspectos de resistencia específicos del mortero tales como su resistencia a la compresión y propiedades que se genera en la mampostería como la resistencia a la compresión axial y compresión diagonal. Además, se realizó un análisis económico teniendo en cuenta aspectos como costos, rendimientos de materiales y mano de obra. Los materiales empleados cumplen con los requisitos según normativa ASTM. Asimismo, las unidades de mampostería son ladrillos de arcilla cocida específicos para muros portantes.

Los resultados obtenidos muestran una ventaja por parte del mortero premezclado tanto desde el punto de vista mecánico como en el aspecto económico donde el mortero predosificado resulta un 9.04 % más económico.

Teniendo en cuenta que ambos morteros cumplen con los requerimientos, en cuanto al mortero tradicional esto no se cumple siempre ya que su eficacia depende de su elaboración y la calidad de sus componentes, sin embargo, demostrándose que el mortero predosificado ofrece mejores propiedades mecánicas y es más económico, su uso es más recomendable.

Palabras clave: mortero tradicional, mortero Predosificado, análisis económico, propiedades mecánicas

Abstract

This article presents a comparative analysis between 2 types of mortars, one traditionally made and one dry pre-dosed. The aim is to determine whether the predosed mortar offers advantages over the traditionally prepared mortar, since the latter is generally prepared under poorly controlled conditions. For this purpose, specific strength aspects of the mortar were evaluated, such as its compressive strength and of the masonry, such as its resistance to axial compression and diagonal compression. In addition, an economic analysis was carried out, taking into account aspects such as costs, material and labor costs. The materials used meet the requirements of ASTM standards. Likewise, the masonry units are baked clay bricks specifically designed for load-bearing walls.

The results obtained show an advantage for the premixed mortar both from the mechanical point of view as well as in the economic aspect, where the premixed mortar is 9.04% more economical.

Considering that both mortars comply with the requirements, as for the traditional mortar this is not always fulfilled since its efficiency depends on its elaboration and the quality of its components, however, demonstrating that the ready-mixed mortar offers better mechanical properties and is more economical, its use is more recommendable.

Keywords: traditional mortar, predosed mortar, economic analysis, mechanical properties

Introduction

Masonry is a construction system that has been developed around the world since before the 1990s, so much so that in countries such as Italy more than 90% of masonry constructions have been built at that time [1]. Currently it is very common to see this construction system in developing countries, this is because it is an economical system [2], however, this system has shortcomings against seismic loads because the components of this system such as bricks and mortar are usually of poor quality, which is why in Asian countries such as Thailand it can be seen that the constructions that have been made over time do not offer safety against seismic events [3].

On the other hand, in Latin America this problem is not indifferent since there is a lot of informality in construction, such is the case of Ecuador where informality covers 39%,[4], this leads to the use of materials that do not meet the minimum requirements.

To this can be added that being the mortar the main component of the masonry as it is the material responsible for adhering the bricks, it must be given adequate resistance, this is achieved with the proper use of cement that due to the population growth that has been generated in many places is a material that is being used more often [5], however, the properties that the mortar can offer will depend greatly on the type of cement to be used [6].

Bearing in mind that mortar is the adhesive that together with the masonry units forms resistant walls, they must be executed with good quality in order to have structures that prevail over time and do not become deficient due to the use of poor construction or inappropriate materials [7].

Therefore, it is important that in the design of masonry the maximum resistance is determined by means of axial compression tests, this information will allow the analysis of the results to have a clearer conception of the allowable resistance, stiffness and stress used in the masonry design [8], thus verifying that the masonry is optimally resistant.

Over time, research has been carried out to improve the compressive strength of mortar, reaching optimal results using pozzolans, since they can help to achieve high short-term strengths, which with traditional mortars with lime alone would be achieved in the long term; in addition, it was found that mortars with lime are resistant to carbonation, and mortars with the addition of pozzolans are not affected by these effects [9].

Another case is that of improving the mortar by using natural additives to improve workability and resistance, since the use of pozzolans such as metakaolin can be a replacement for cement and can even provide greater resistance, but it produces a deficiency in workability,

which is why the use of bio-based additives can help to have a more efficient product, since the use of these components in the mortar improves resistance by 35% [10].

In general, there are several researches looking for improvements in mortar and not only compression properties but also fluidity, shrinkage and traction. However, when replacing this input under certain conditions, mortar with bottom ash does improve the flow, but decreases the compressive strength, on the other hand, it increases the total shrinkage, and increases the tensile strength of the mortar. In addition, the tensile deformation capacities of mortar containing bottom ash are higher than those of plain mortar [11].

Similarly, seismic upgrading techniques have been evaluated in existing masonry structures because they comprise a very common structural material and most historic structures have it. Thus, due to their age and vulnerability, masonry buildings generally need more structural retrofitting [12].

On the other hand, it is not only necessary to know or seek improvements for resistance since it is also very common to see problems referred to durability in cement-based materials, including mortars, which are also affected by permeability problems among others and that is why it is necessary to develop a material as less prone to these attacks and improve it in general since its proper functioning must be guaranteed without generating higher cost [13].

It is well known that in construction in general, not only quality aspects should be contemplated, but also economic ones, since these should go hand in hand so that losses or deficient constructions are not generated, which is why the proper management of resources in construction projects can generate substantial savings in time and costs. Given that construction is a labor-intensive industry [14],

It should be noted that although this study will focus on masonry, there are other construction systems that are more economical than masonry, such as reinforced concrete walls with electro welded mesh and steel fiber reinforced concrete walls [15], this only looking at it from the economic point of view is a clear example that the performance and the construction process influence too much when opting for a construction system, so any method or material that helps to improve the construction processes and that additionally reduce costs, help masonry not to be seen as an empirical system.

Taking into account that one of the fundamental uses of mortar is referred to masonry, an adequate quality control should be considered and improvements should be sought to help solve deficiencies that occur on site, in many countries the use of ready-mixed mortar is beginning to be used for both mortar and concrete, being more common for the latter, however for mortars it is beginning to take relevance since it can solve the problems of masonry already mentioned.

The strategy of elaborating premixed or pre-dosed mortars is due to the control of the materials and the adequate dosage. This mortar works best with high sand/cement ratios, which demonstrates that dry ready-mixed mortar is more effective as the cement content is reduced or controlled, and therefore can be produced and marketed with adequate quality assurance. In addition, more benefits are generated in terms of shrinkage and workability [16].

That is why dry ready-mixed mortars are a great alternative to the shortcomings in work, since being a mortar prepared in a factory it is expected to provide good quality, but it should also be seen from the economic point of view because depending on the dry ready-mixed mortar used, different economic balances will be obtained, it is also necessary to know what is the resistance achieved by this type of mortar because as is known each work can have different demands.

The purpose of this study is to know the properties and the benefit-cost ratio generated by using dry premixed mortars, since this type of mortars are usually sold in bags, just like cement, and are called ready-mixed mortars, which only add water and are ready to use. For this purpose, a mortar from the study area, Chiclayo, Peru, will be used, the one that is most in demand and is expected to be of great benefit. The parameters of the masonry standard E070 of the national building regulations [17] will be used as references.

Materials and experimental methodology

For this study, Portland cement type 1 and coarse sand with a bulk density of 2,103 g/cm³ and an absorption of 6.11% were acquired, which is the most representative type of sand for the elaboration of mortars, in addition to this the granulometric analysis was carried out according to ASTM C136 [18], the aggregate for mortar must comply (Figure 3). Thus, for the Pre-Dosed mortar, the one with the most relevance in the study area was chosen (Mortar for settled, n.d.).

On the other hand, for the bricks the standards for load-bearing walls were used which must comply with the requirements of the E070 standard of the RNE, these in turn went through a series of tests to know their properties. With all this, tests will be carried out for both the traditional mortar and the pre-dosed mortar of compressive strength and axial and diagonal compression tests of masonry prisms, this is finally accompanied by a cost analysis to know the most detailed use of each option.

Properties of mortar

For the elaboration of the mortar, it is necessary to know certain properties of the sand such as unit weight and granulometry and the specific weight, these tests were elaborated considering the respective Peruvian standards.

For the unit weight test, the material that occupies a certain volume was weighed. (Figure 1)



Figure 1: Weight of the aggregate to know the unit weight.

It was thus known that the aggregate has a unit weight of 1.36 g / cm³, then proceeded to perform the granulometry test, began by placing the sieves in the following order: N°4, N°8, N°16, N°30, N°50, N°100 and bottom, to then place the significant sample and proceed to sieving.

With the necessary data of the aggregates already obtained, the mixtures are elaborated for this purpose, a dosage of cement-sand mortar 1:4 was used, and the dry pre-dosed mortar was also used.

Table 1. It shows the volume dosage of the traditional mortar that is more common in constructions and the pre-Dosed mortar which already comes with a factory dosage.

Table 1: Proportion in volume of the mortar.

Mortar	Denomination	Proportion
Traditional cement: Sand	MT	1: 4
Predosificado	ML	--

Table 2. It shows the amount of materials per cubic meter of the traditional mortar mixture. Additionally, to determine the amount of water required, a fluidity close to $110 \pm 5\%$ was sought as indicated by ASTM C109 [19]. For this purpose, fluency tests were carried out following the guidelines of ASTM C 1437 [20].

Table 2: Dosage of the mortar per cubic meter.

Proportion	Cement (kg)	Sand (m³)	Water (liters)
1:4	368.5	0.98	320.6

With respect to the Predosed mortar, it was decided to place the water sent by its manufacturer. Figure 3. It shows the flow test that guaranteed a correct workability de the mortars that are the object of study.

The compressive strength test specimens were mortar cubes with a length of 50 mm, as shown in Figure 4. For its elaboration, the procedure described in ASTM C109 was followed. To do this, the materials were mixed, and the mixtures were placed in cubic molds. These were left in water until the day of their trial at 7,14,21 and 28 days. A total of 24 cubes were produced.



Figure 2: Measurement of mortar expansion.



Figure 3: Traditional mortar cubes.



Figure 4: Pre-dosed mortar cubes

The compressive strength tests were carried out on a Universal Test Machine with a load capacity of 1 000 kN. Three cubes were tested at each of the following ages: 7, 14, 21 and 28 days.

Axial and diagonal compression test

For the axial compression test of piles, the provisions of NTP 399.605 were followed, units of fired clay called King Kong 18H brick were used.

For the elaboration of the piles, the bricks were moistened to prevent it from removing water from the mortar, after that the piles of 3 units with a 1.5 cm joint were made. When the batteries are ready to be tested, the respective measures are taken, and the brakes are made so that the applied load is uniform.

The axial compressive strength tests were performed on a Universal Test Machine with a load capacity of 1 000 kN.



Figure 5: Axial compression test.

For the elaboration of walls for the diagonal compression test, the provisions of NTP 399.621 were followed, King Kong bricks of 18 H were used, these were settled with traditional 1:4 mortar and dry pre-dosed mortar, both with joints of 1.5 cm both horizontal and vertical, once ready we proceed to the Facing and the taking of respective measures for later testing.

The diagonal compressive strength tests were carried out on a wall press with a load capacity of 20000 kgf.



Figure 6: Axial compression test of walls.

cost analysis

To perform the cost analysis, the costs and yields of the materials obtained during the process of this research were considered, which are described below.

Masonry units

For the experimental case, the elaborated walls were measured and the bricks that were part of its elaboration were counted, both for the traditional mortar and for the dry pre-dosed mortar. Then the number of masonry units used was divided by the sum of the areas of the 3 walls of the same type and the performance of bricks per square meter was determined. Finally, the product of the price of each masonry unit for this performance provides us with the cost of masonry units for a m² of wall.

Adherent

In this case you want to know the true performance of the different adherents, since the material may be missing or surplus.

To know the real performance of the mortar traditionally elaborated, it will be verified in practice if the quantity of the theoretical materials resembles the experimental quantity, from this a yield of materials per square meter of wall will be obtained. Finally, with the product of the unit price of each component for its quantity that is required for each square meter, the cost will be determined.

In the case of dry pre-dosed mortar, it will be verified if the performance provided by the technical sheet of the product is effective or some correction is required for excess or defect, with all this a real yield of the product will be obtained and by multiplying this by the unit price the cost it demands is obtained.

Labor

In this section the performance of the hand will be found, taking into account the time it takes the operator to make the walls with each type of adherent, therefore, its performance will be determined by dividing the built area by the time it takes, and in turn this result will be affected by the time of an 8-hour working day in accordance with the law.

Finally, the unit prices per hour of each member of the crews were obtained thanks to the 2021-2022 salary table established by the federation of civil construction workers of Peru (table 3), to multiply it with the required amount and determine the cost of these per m².

Table 3: Price in soles per hour of each member of the crew.

Foreman	S/.29.08
Operative	S/.24.23
Pawn	S/.17.29

Results and discussion

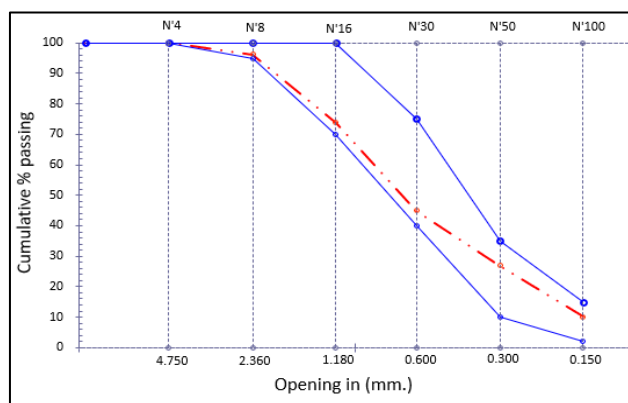
Granulometric analysis

The fine aggregate meets the ASTM C144 requirement, which specifies the granulometry of the mortar aggregate.

Table 4: ASTM C 144 Requirement

ASTM C144 MESH	% WHAT HAPPENS
N°4	100
N°8	95-100
N°16	70-100
N°30	40-75
N°50	10-35
N°100	2-15
N°200	0-2

Figure 7: Granulometric curve of the aggregate for the elaboration of traditional mortar, it can be seen that through the sieve N°4 the percentage that passes is 100%, by the sieve N°8 passes 96.2%, by the sieve N°16 passes the 73.8%, , by the sieve N°30 passes the 45%, by the sieve N°50 passes the 26.9% and by the sieve N°100 passes the 10.1%, with this we can ensure that the aggregate used is suitable for the elaboration of the mortar.



Properties of mortar

In Figure 11 we can see the results obtained at 7, 14, 21 and 28 days of the compressive strength for traditional mortar and for the pre-dosed mortar.

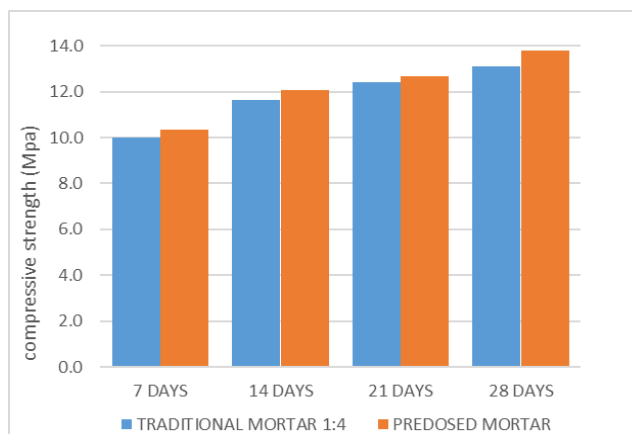


Figure 8: Evolution of the compressive strength of traditional and pre-dosed mortar.

The results obtained show that the traditional 1:4 mortar and the premixed are mortars that exceed what is required by the ASTM C-270, which mentions a required resistance of 12.4 Mpa at 28 days, while the Predosificado mortar achieves a resistance of 13.77 Mpa, surpassing the traditional 1:4 mortar that achieves a resistance of 13.11 Mpa.



Figure 9: Percentage obtained from mortars according to ASTM C-270 requirement

The results obtained show that the pre-dosed mortar achieves a greater resistance than the premixed mortar, this is because being an industrialized product it has a controlled dosage (Mortar for settling, n.d.), on the other hand, the traditional mortar tends to have variations in terms of its resistance depending on the characteristics of the materials and the control in the dosage that is granted. It can be seen in Figure 11 that the pre-dosed mortar has 111.1% efficiency according to the ASTM C-270 requirement and the traditional mortar 105.8%.

The compressive strength of the pre-dosed mortar is 5.3% more than the one traditionally elaborated, mentions that the pre-dosed mortar can reach up to 10% more resistant, which proves that it is a mortar of greater efficiency if resistance is spoken, this can be attributed to the controlled conditions in which it is elaborated.

Axial and diagonal compression tests

Axial compression of masonry piles

The results obtained were compared with the requirement of the Peruvian standard of RNE e070, which mentions that the batteries must obtain a minimum resistance at 28 days of 6.4 Mpa

The pre-dosed mortar obtained an axial compression resistance of 6.7 Mpa, while the traditional mortar achieved an axial compressive strength of 6.36 Mpa, slightly below the requirement.

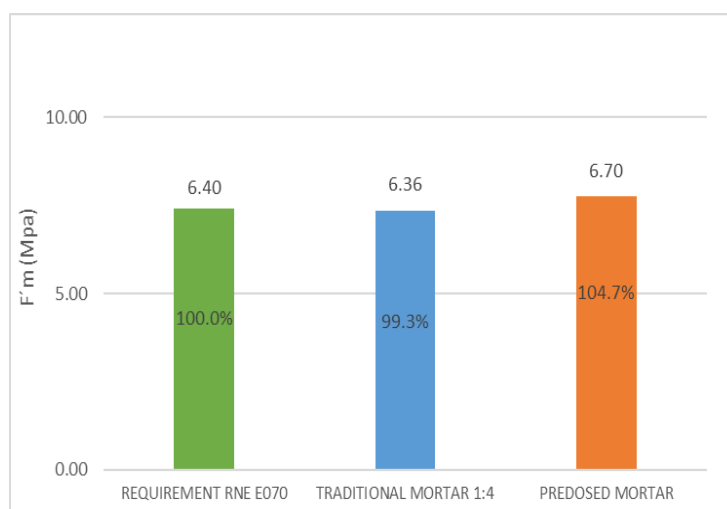


Figure 10: Percentage obtained from the axial compression test according to the requirement of RNE e070.

The results obtained show that the pre-Dosed mortar offers an advantage in terms of the traditionally elaborated mortar since it reaches a percentage of 104.7% according to the requirement of the RNE e070, while the traditional mortar only reaches 99.3%, it can be said that the pre-dosed mortar is more efficient, which makes its use advisable.

The difference in the results refers to the data obtained in the compression test of the mortar, where it is reflected that the pre-dosed mortar is more resistant, in this test a similar result was obtained, since it is the pre-dosed mortar that makes the difference with respect to the traditional one.

Diagonal compression of masonry walls

The results obtained were compared with the requirement of the Peruvian standard of RNE e070, which mentions that the batteries must obtain a minimum resistance at 28 days of 0.79 Mpa

The pre-dosed mortar obtained a diagonal compressive strength of 0.88 Mpa, while the traditional mortar achieved a diagonal compressive strength of 0.87 Mpa, both mortars meet the RNE requirement, however, the pre-dosed mortar offers an advantage, this indicates that in the face of diagonal compression effects both mortars have a better behavior.

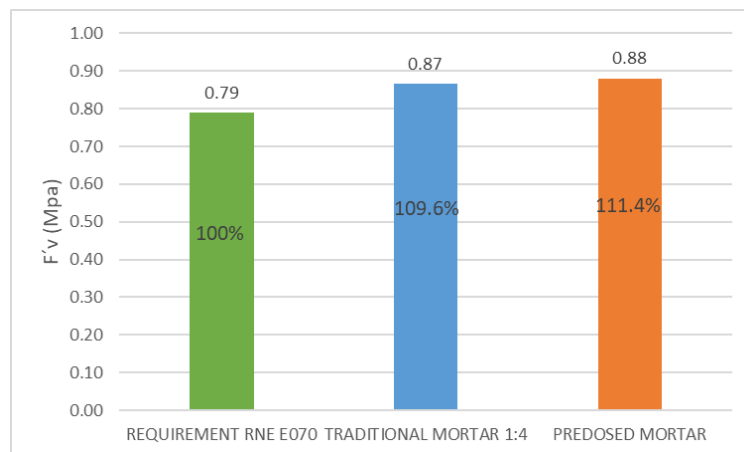


Figure 11: Percentage obtained from the diagonal compression test according to the requirement of RNE e070.

The results obtained show that the pre-dosed mortar offers an advantage over the traditionally made mortar since it reaches a percentage of 111.4% according to the requirement of the RNE e070, while the traditional mortar reaches 109.6%, it can be said that the pre-dosed mortar is more efficient, which makes its use advisable.

As in the test of masonry piles, the pre-dosed mortar offers greater efficiency which is due as already mentioned to the quality control it has, compared to the traditional mortar this at the time of its elaboration can generate certain changes or alterations, which the pre-dosed mortar has controlled.

Cost analysis

To carry out the cost analysis, the construction process of masonry walls was considered, in whose departure it was necessary to know 2 important aspects, these are the cost of labor and the cost of the materials in which the masonry units and the adherent are contemplated.

The comparative labor costs are shown in Figure 12, which allows us to appreciate that with the traditional mortar the price obtained is S / 68.99. On the other hand, for the dry pre-dosed mortar a lower value is reflected, because its performance is higher with a different crew, the price obtained is S / 40.44. With this we can conclude that in this aspect the ready-mix mortar demands lower cost.

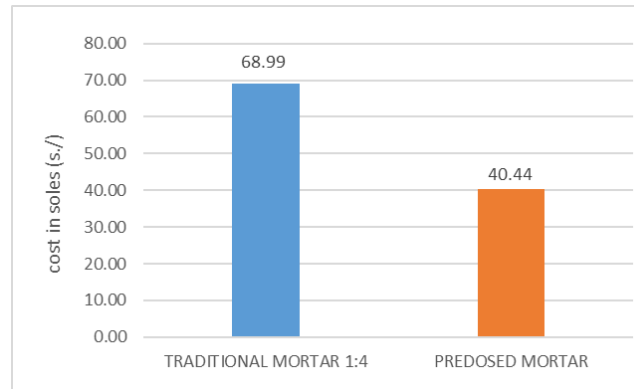


Figure 12: Economic comparison of mortar labor (price in soles)

Labor prices vary due to the fact that different yields and different crews were considered.

For the traditional mortar was considered a crew composed of 0.1 Foreman, 1 operator and 0.5 pawn with a yield of 4.15 m² / day. This leads to a cost of S./68.99 per m²

For the dry pre-dosed mortar, a crew composed of 0.1 Foreman, 1 operator and 0.25 laborer with a yield of 6.22 m² /day was considered. This leads to a cost of S./40.44 per m².

It can be seen that the price decreases using pre-dosed mortar, this is because its use generates less personnel and greater performance, this because construction processes such as dry mixing are avoided, in addition to the work involved in this process, this leads to that time being used in performance and thus its use is effective.

The comparison of material costs is shown in Figure 13, which shows that the traditional 1:4 mortar requires a cost in materials per m² of S/44.11 and their pre-dosed mortar requires a cost in materials per m² of S/63.11. With this we can conclude that in this aspect the ready-mix mortar demands a higher cost than traditional mortars.

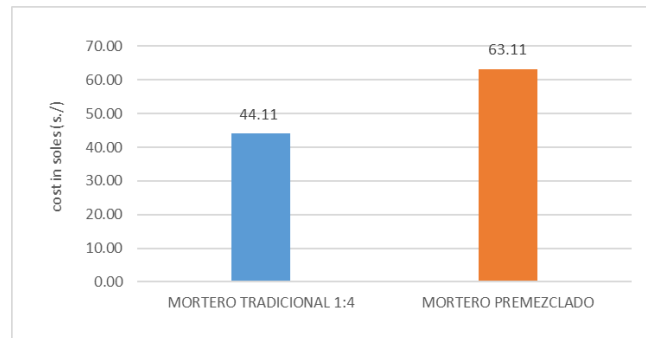


Figure 13: Economic comparison of material cost of mortars (price in soles)

In this case it can be seen that the cost of the pre-dosed mortar is higher than if you bought the mortar supplies separately, however, the cost of the pre-dosed mortar may vary depending on the place and the demand it has. An advantage that the pre-dosed mortar has is its easy storage and easy transport on site, which is more complicated than if you had the inputs separately.

To obtain the analysis of experimental costs, the aforementioned aspects are taken into account, which are labor, materials and equipment, figure 14 reflects the comparison of the price in soles per m² of wall, it is observed that the traditional 1:4 mortar generates a cost of 92,201 soles / m² and the predosified mortar generates a cost of 76,539 soles / m².

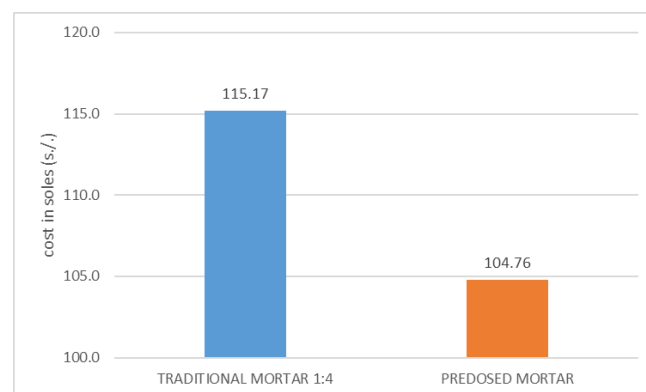


Figure 14: Economic comparison of mortars (price in soles)

In general, we can say that although the pre-dosed mortar can have a high cost, this is compensated at the time of its application since it generates savings in labor and provides a greater advance.

With this we can say that also in the economic aspect it is better than the traditional mortar, so its use is the most optimal and recommended, since it offers everything that is sought in work that is effectiveness, quality, and economy.

Conclusions

- The comparative analysis was carried out between traditional mortar and predosed dry mortar. In which it was obtained that both the prisms and the masonry walls that achieve a greater resistance are those made with pre-dosed mortar, this allows us to conclude that it is a favorable option to be used in masonry since its use is viable.
- It can be said that the best option, taking into account the variables studied, is the dry predosed mortar since it offers a considerable improvement in terms of mechanical properties and a decrease in costs compared to traditional mortar.

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References

- [1] A. Formisano, G. Chiumiento, y E. J. Dessì, “Laboratory tests on hydraulic lime mortar reinforced with jute fibres”, *Open Civ. Eng. J.*, vol. 14, núm. 1, pp. 152–162, 2020.
- [2] “Design of isolated masonry housing using re-cycled rubber materials”, Org.uk. [En línea]. Disponible en: <https://www.masonry.org.uk/downloads/design-of-isolated-masonry-housing-using-re-cycled-rubber-materials/>. [Accessed: 15-Dec-2022].
- [3] P. Joyklad et al, "Strength Enhancement of Interlocking Hollow Brick Masonry Walls with
- [4] J. Véliz Torresano y S. Díaz Christiansen, “El fenómeno de la informalidad y su contribución al crecimiento económico: el caso de la ciudad de Guayaquil”, *J. Econ. Finance Adm. Sci.*, vol. 19, núm. 37, pp. 90–97, 2014.
- [5] Y. F. Silva, Universidad del Valle (Colombia), D. A. Lange, S. Delvasto, University of Illinois at Urbana-Champaign (United States), Urbana, y Universidad del Valle (Colombia), “Effects of the incorporation of residue of masonry on the properties of cementitious mortars”, *rdlc*, vol. 19, núm. 3, pp. 407–421, 2020.
- [6] K. Tahereh and Eskandari-Naddaf Hamid, "Mechanical Properties and Microstructure Evaluation of Cement Mortar with Different Cement Strength Classes by Image Analysis," *The Arabian Journal for Science and Engineering. Section B, Engineering*, vol. 47, (4), pp. 4763-4783, 2022.
- [7] L. Zhu y Z. Zhu, “Reuse of clay brick waste in mortar and concrete”, *Adv. Mater. Sci. Eng.*, vol. 2020, pp. 1–11, 2020.
- [8] A. Azevedo et al., “Compression behaviour of clay bricks prisms, wallets and walls - Coating influence”, *rdlc*, vol. 18, núm. 1, pp. 123–133, 2019.
- [9] A. F. Espitia Morales y N. Torres Castellanos, “Assessment of the compressive strength of lime mortars with admixtures, subjected to two curing environments”, *Ing. Investig.*, vol. 42, núm. 2, p. e91364, 2021.
- [10] Y. Fang et al., “Bio-based admixture (black tea extraction) for better performance of metakaolin blended cement mortars”, *Materials (Basel)*, vol. 15, núm. 11, p. 3994, 2022.

- [11] P. Markpiban, W. Krudam, y R. Sahamitmongkol, “Investigation of flow, compressive strength, shrinkage, and tensile properties of mortar with internal curing bottom ash”, *Results in Materials*, vol. 15, núm. 100296, p. 100296, 2022.
- [12] P. D. Gkournelos, T. C. Triantafillou, y D. A. Bournas, “Seismic upgrading of existing masonry structures: A state-of-the-art review”, *Soil Dyn. Earthq. Eng.*, vol. 161, núm. 107428, p. 107428, 2022.
- [13] P. Huang et al, "Microstructural Properties of Cement Paste and Mortar Modified by Low Cost Nanoplatelets Sourced from Natural Materials," *Materials*, vol. 11, (5), pp. 783, 2018.
- [14] M. E. Shehata y K. M. El-Gohary, “Towards improving construction labor productivity and projects’ performance”, *Alex. Eng. J.*, vol. 50, núm. 4, pp. 321–330, 2011.
- [15] C. Julián, A. William, y E. Fabián, “Evaluación de los costos de construcción de sistemas estructurales para viviendas de baja altura y de interés social”, *Ing. Investig. Tecnol.*, vol. 16, núm. 4, pp. 479–490, 2015.
- [16] J. L. Plawsky, S. Jovanovic, H. Littman, K. C. Hover, S. Gerolimatos, y K. Douglas, “Exploring the effect of dry premixing of sand and cement on the mechanical properties of mortar”, *Cem. Concr. Res.*, vol. 33, núm. 2, pp. 255–264, 2003.
- [17] “Servicio Nacional de Capacitación para la Industria de la Construcción”, *Gob.pe*. [En línea]. Disponible en: <https://www.gob.pe/institucion/sencico/informes-publicaciones/887225-normas-del-reglamento-nacional-de-edificaciones-rne>. [Accessed: 17-Sep-2022].
- [18] “Método de prueba estándar para análisis de tamiz de agregados finos y gruesos”, *Astm.org*. [Online]. Disponible en: <https://www.astm.org/c0136-06.html>. [Accessed: 08-Oct-2022].
- [19] ASTM C109 Method for determining the compressive strength of hydraulic cement mortars using cubic specimens 50 mm (2in) side, American Society for Testing and Materials.
- [20] ASTM C1437 Standard Test Method for Hydraulic Cement Mortar Flow, American Society for Testing and Materials.