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Influence of sodium citrate on resistance of adherence of gypsum re-used

Anderson Rubens Bispo de Araújo B.Eng.[a*], Bruno Carlos de Araújo Alves B.Eng.[a], Francesco Sarti B.Eng.[b] and Yêda Vieira Póvoas Tavares D.Sc.[c]

[a] Escola Politécnica de Pernambuco, Universidade de Pernambuco, Recife, Brasil.
[b] Università degli Studi di Perugia, Perugia, Italia.
[C] Universidade de São Paulo, São Paulo, Brasil.

*Corresponding author: E-mail: andersonrba@yahoo.com.br

ABSTRACT

With the growth of construction, gypsum is widely used in Brazil. Nonetheless, its application as a coating generates large waste due to labor disqualified and the improper disposal. Because of this waste production which can reach 50% of all municipal solid waste, it was interesting in making a comparison between the adhesion strengths for mixtures of gypsum residue and the addition of retardant additive (sodium citrate). The objective of this research is to evaluate the influence of sodium citrate in the adhesive strength of the gypsum plaster with or without the addition of gypsum waste. Sodium citrate was inserted into the mixture in the proportion of 0.06% over the weight of gypsum. In the preparation of gypsum panels with and without residue and sodium citrate, it was waited to dry and followed NBR 13528 (2010) to evaluate the bond strength for each plaster section. The results demonstrate that sodium citrate interferes with the adhesive strength of the gypsum plus residue mixture. Even with a longer drying waiting-time, the adhesive strength is unchanged. Therefore, depending on the purpose of the coating, it should be have in mind for the reuse of gypsum residue on the handle retarder, as it can alter the bond strength interfering with the final quality.

Keywords: plaster, waste, handle retarder, sodium citrate, adhesion

INTRODUCTION

When it comes to internal coating walls, the main binders used in Brazil are cement, lime and plaster, most notably the first. However, using the conventional model with mortar containing cement has lost space for the use of gypsum slurry for coating. This growth occurs due to some characteristics that give the plaster quite satisfactory competitive conditions, including the rapid hardening, which enables higher productivity and the smoothness of the hardened surface that favors the quality of the finish (JOHN and CINCOTTO, 2010).

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In 1995, Dias studied the main characteristics of the plaster - Surface resistance, adhesive strength, permeability, absorption and desorption. The highlights of his job, loss of grip on the base coat and the appearance of cracks interface, which explains the poor quality of sand used at the base. Antunes (1999) examined the A / G ratio of 0.69 and with addition of 13% of hydrated lime on the gypsum binder in the paste and found a reduction in pore volume, thereby improving the strength and increasing the useful time.

The formation of gypsum crystallization of the microstructure of the binder hydration process thus influences the mechanical characteristics of the plaster. Several factors can change this formation: presence of accelerator additive / handle retardant, water / plaster and the presence of impurities.

As studies, addition of sodium citrate in pure gypsum binder, alter the kinetics of formation of dihydrate crystals, decreasing the cohesiveness of the particles and thus reducing the compressive strengths.

it is needed to study the influence of sodium citrate gypsum binders with and without residue on the principal property of a coating: adhesion strength.

Carasek (2014) established a number of factors that influence the mortar adhesion to the substrate. These include: weather conditions (temperature and wind); mortar (rheology, initial adhesion, water retention); substrate (water suction, roughness, porosity); implementation (impact energy).

According Casarek (1996), the water suction capability is important for the mortar adhesion. Research Müller (2010) and Balayssac *et al.* (2011) found that when the substrate is saturated, the grip performance is inferior to the dry substrate. Although the gypsum having a lower cure time of the cement mortar, it is important to control the moisture content of the substrate.

Roughness in the substrate can be improved by applying roughcast. The traditional roughcast performed with the trowel improves the adhesion between the coating and various substrate such as concrete (Muller, 2010) and ceramic masonry block (KAZMIERCZAK *et al.*, 2009).

For a good application to the substrate, it is necessary to acquire certain consistency pulp, which occurs just before the start handle. As you approach the end of handle, the folder loses plasticity, making it difficult to work plasterer, because the crystalline structure is very cohesive. This event takes the name of consistency useful range for the coating performance (ANTUNES and JOHN, 2000).

The motivation for the development work is based on the lack of studies of gypsum coating and its residue, to give a comparative and qualitative analysis and also the absence of specific standard tensile adhesion strength test in these types of coatings.

This research aims to experimentally evaluate the adherence of plaster coatings, considering the inclusion of the waste and handle retardant additive.

MATERIALS AND METHODS

1. Characterisation of materials

For the characterization of plaster powder and gypsum waste, the bulk density tests were carried out - MB 3468 (ABNT, 1991) and laser granulometry of the Masterizer Micro equipment. The granulometric composition of the residue used

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was obtained from the results of research conducted by Cavalcanti *et al.* (2012) (Table 1).

Table 1 - Final grain size composition. (Cavalcanti *et al.*, 2012).

Sieve size (mm)	Percent retained	Percent passing
0,075	0,50%	0,50%
0,106	1,00%	1,50%
0,212	1,50%	3,00%
0,3	18,00%	21,00%
0,425	27,00%	48,00%
0,6	21,00%	69,00%
0,85	19,00%	88,00%
1,18	12,00%	100,00%
TOTAL	**100,00%**	**100,00%**

2. Materials and mashing

For this study, it was collected in the market samples of the same batch of plaster. The residue was already produced in the laboratory by manual crushing and sieving to obtain such particle size. The residue was added as a replacement to the mixture in the proportion of 10% over the mass of the plaster.

For the amount of handle retardant additive, followed by the research Alves *et al.* (2012) which is added to the mass of plaster 0.06% sodium citrate.

The water / dry material was determined by the normal consistency test as MB 3469 (ABNT, 1991) using a modified Vicat apparatus. We obtained as a result of penetration of the needle 0.6 to 31 cm.

The method adopted for the blends followed the standard MB 3469 (ABNT, 1991), where the powdering time, waiting and mixture are, respectively, 1 min, 2 min and 1 min. In mixtures containing residue was used half of the time because the residue functions as a throttle grip. In plaster mixture with additives, to advance the process to handle increased duration of mixing for 20 minutes.

Use of the additive: additive was premixed to the mixing water before contacting the plaster.

Add the residue: the residue was premixed to the plaster before contact with the mixing water.

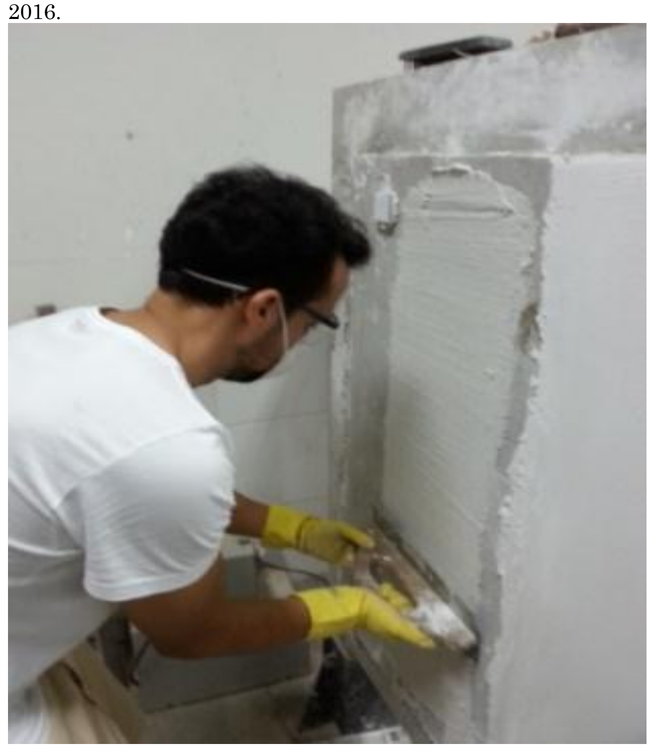
3. Application of the coating

It was carried out four types of mixing for the production of coating with four different panels: gypsum slurry; gypsum slurry with additive; gypsum slurry with residue; and plaster folder with residue and additive.

The application of the mixtures were on a porch with masonry coated mortar. The porch area is 1.5 m x 1 m and each cloth was completed with an approximate area of 0.3 m x 1.0 m.

To apply the coating, it was used a steel trowel width of the plaster cloth - 30 cm (Figure 1), obtaining a thickness of 5 mm.

Figure 1 - The plaster coating application. Source: Authors, 2016.



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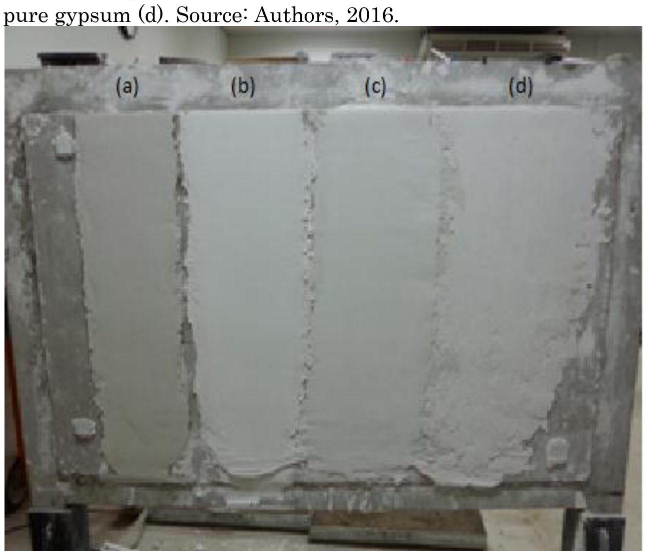
The four panels were made in the vertical (Figure 2). From left to right, it represents, respectively: gypsum plaster (gypsum + residue) with the additive; plaster mortar (plaster + residue); plaster with additives; and pure gypsum.

Figure 2 - Four coating netting residue with gypsum and additive (a); plaster residue with (b); Plaster with an additive (c); pure gypsum (d). Source: Authors, 2016.



4. Grip strength test

The pull-out test followed the recommendations of the NBR 13528 (ABNT, 2010).

After waiting for drying the coating for 7 days, the cutting process began with a 50 mm saw in diameter coupled to a drill (Figure 3). The spacing between each cut was 5 cm, to try to make the most possible area of the cloth. In each cloth was made 12 cuts.

The pullout test for the four fabrics was performed on day 8 healing environment, but there was a further embodiment pull-out on day 18 for the plaster cloth residue and citrate to analyze if there was variation in the bonding strength.

After the cuts, the cleaning was done to remove the dust and the pellets were glued on each specimen with epoxy glue, taking care to support tablets in cardboard pieces (Figure 4).

Figure 3 - Cut the cloth. Source: Authors, 2016.

Figure 4 - Cloths with glued inserts. Source: Authors, 2016.

After waiting 24 hours for drying of the glue, it began the tearing of the specimens using the aderimeter (Figure 5).

The cuts were numbered and registered types of rupture of each specimen (figure 6). For example, the specimen 1 for the pure plaster cloth was found in the breakage-plaster substrate interface.

Figure 5 - Aderimeter applying force. Source: Authors, 2016.

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Figure 6 - Proof Body and rupture. Source: Authors, 2016.

RESULTS AND DISCUSSION

After the implementation of the pull-out test, we obtained the results shown in Table 2.

Table 2 - Load, tension and rupture place for 8 days of curing for Gypsum, Gypsum+Citrate, Gypsum+Residue and Gypsum+Residue+Citrate panels. (Authors, 2016).

Gypsum

Specimen	Load (Kgf)	Tension (MPa)	Rupture place
1	33	0,16	Substrate/Gypsum
2	26	0,13	Substrate/Gypsum
3	47	0,23	Substrate/Gypsum
4	29	>0,14	Gypsum
5	61	>0,30	Gypsum
6	32	>0,16	Gypsum/Glue
7	12	0,06	Substrate/Gypsum
8	76	>0,38	Gypsum/Glue
9	35	>0,17	Gypsum/Glue
10	61	0,30	Substrate/Gypsum
11	36	>0,18	Gypsum
12	82	>0,41	Gypsum

Gypsum + Citrate

Specimen	Load (Kgf)	Tension (MPa)	Rupture place
1	49	>0,24	Gypsum/Glue
2	15	>0,07	Gypsum/Glue
3	63	0,31	Substrate/Gypsum
4	29	>0,14	Gypsum
5	60	>0,30	Gypsum/Glue
6	63	0,31	Substrate/Gypsum
7	57	>0,28	Gypsum/Glue
8	29	>0,14	Gypsum/Glue
9	23	0,11	Substrate/Gypsum
10	78	0,39	Substrate/Gypsum
11	60	0,30	Substrate/Gypsum
12	39	0,19	Substrate/Gypsum

Gypsum + Residue

Specimen	Load (Kgf)	Tension (MPa)	Rupture place
1	64	0,32	Substrate/Gypsum
2	66	0,33	Substrate/Gypsum
3	65	0,32	Substrate/Gypsum
4	39	>0,19	Gypsum/Glue
5	51	>0,25	Gypsum/Glue
6	96	0,48	Substrate/Gypsum
7	81	0,40	Substrate/Gypsum
8	44	0,22	Substrate/Gypsum
9	40	>0,20	Gypsum/Glue
10	61	0,30	Substrate/Gypsum
11	34	0,17	Substrate/Gypsum
12	39	>0,19	Gypsum/Glue

Gypsum + Residue + Citrate

Specimen	Load (Kgf)	Tension (Mpa)	Rupture place
1	39	>0,19	Gypsum
2	31	>0,15	Gypsum
3	60	>0,30	Gypsum
4	28	>0,14	Gypsum
5	30	>0,15	Gypsum
6	42	>0,21	Gypsum
7	42	>0,21	Gypsum
8	33	>0,16	Gypsum
9	25	>0,12	Gypsum
10	30	>0,15	Gypsum
11	50	>0,25	Gypsum
12	51	>0,25	Gypsum

According to NBR 13528 (2010), when the break is in the gypsum-adhesive interface and in the

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plaster, the value shown is different from the actual amount of adhesion. This actual value is greater than the value obtained from the test. Therefore, the values given the greater than sign (>).

Note in the plaster cloth residue and citrate, breaks all the samples in the plaster, and therefore the actual value of adhesion tension is greater than that measured for each specimen.

From Table 2, Table 3 was developed showing the average adhesion strength, the standard deviation and coefficient of variation of each plaster cloth.

Table 3 - Average resistance of grip, standard deviation and coefficient of variation for 8 days of cure. (Authors, 2016).

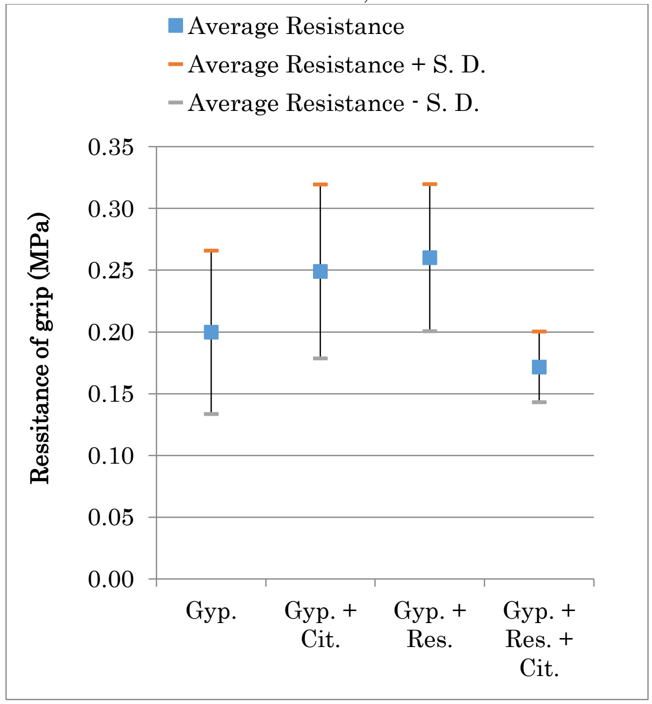
8 days of cure	Gyp.	Gyp.+Cit.	Gyp.+Res.	Gyp.+ Res. + Cit.
A. R. G. (MPa)	0,20	0,25	0,26	>0,17
S. D. (MPa)	0,07	0,07	0,06	0,03
C.V. (%)	33	28	23	17

A. R. G. – Average Resistance of Grip; **S.D.** - Standard Deviation; **C.V.** - Coefficient of Variation; **Gyp.** - Gypsum; **Cit.**- Citrate; **Res.** – Residue.

From Table 3, the graphics were generated: variation of tensile bond strength including the standard deviation (Figure 7); increase and decrease the bond strength of the last three gypsum panels compared to pure gypsum (Figure 8); and coefficient of variation graph of the four panels (Figure 9).

The gypsum panels, gypsum and gypsum with citrate residue obtained bond strength values equal to or greater than 0.20 MPa (Ra ≥ 0,20 MPa) serving NBR 13749 (1994) where for inner walls of plaster or ceilings, the minimum required value is 0.20 MPa. But the plaster cloth with residue and citrate, obtained an amount exceeding 0.17 MPa, but no one knows for sure if it meets the minimum value.

Figure 7 - Variation of tensile bond strength including the standard deviation. Source: Authors, 2016.



Gyp. – Gypsum; **Cit.** –- Citrate; **Res.** – Residue.

Looking at Figure 8, there is an increase of 30% in resistance in plaster cloth waste. In the plaster cloth residue and citrate there was a decrease in the adhesive strength 14%. This decrease may have been caused by the presence of moisture in the plaster cloth residue and citrate, although all panels have the same cure time.

What differentiated latter cloth was how the inserts are bonded. While the other cloths, the tablets were glued on the 7th day of drying, the cloth with citrate and residue, the tablets were glued on the 4th day. Therefore, the tablets may have hindered the healing process hindering the heat exchange and air with the medium.

Another factor that supports this hypothesis the last cloth is that all the breaks were in plaster and so, as the material took to dry, the driest part was at the outside, while the inside was still damp.

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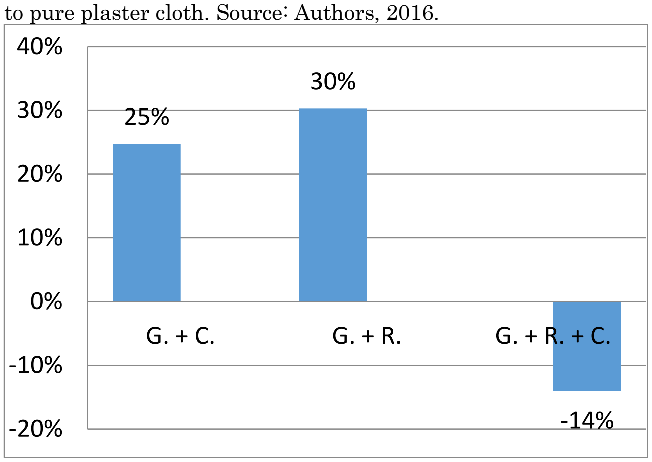
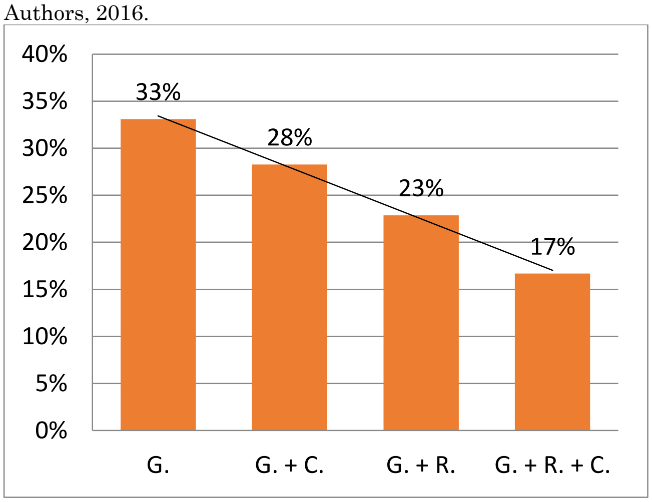
Figure 8 - Increase and decrease in adhesive strength compared to pure plaster cloth. Source: Authors, 2016.



G. – Gypsum; **C.** – Citrate; **R.** – Residue.

The coefficient of variation showed an almost linear decrease according to the graph in Figure 9. In the pure plaster cloth, the CV was high compared to the 25% acceptable. But in all the cloths with residue, CV was close to ideal. In the plaster cloth residue and sodium citrate CV was low, indicating a low variation.

Figure 9 - Coefficient of variation for each plaster cloth: Source: Authors, 2016.



G. – Gypsum; **C.** – Citrate; **R.** – Residue.

On day 18 it was made a new pull-out test for gypsum residue and citrate cloth to check whether the tack changed over time for that cloth (Table 4). Notice a change in the breaking behavior which is not located only in plaster. As Table 3, there is break in the substrate-interface plaster and glue.

Table 4 - Load, tension and rupture place for 18 days of cure.

Gypsum + Residue + Citrate			
Specimen	**Load (Kgf)**	**Tension (MPa)**	**Rupture place**
1	41	0,20	Substrate/Gypsum
2	43	>0,21	Gypsum
3	57	>0,28	Gypsum
4	27	>0,13	Gypsum /Glue
5	24	>0,12	Gypsum
6	27	>0,13	Gypsum /Glue
7	28	>0,14	Gypsum
8	38	>0,19	Gypsum
9	35	0,17	Substrate/Gypsum
10	19	>0,09	Gypsum /Glue
11	37	>0,18	Gypsum
12	35	>0,17	Gypsum

Note again that the actual adherence tension to most specimen is greater than the measured value.

It was generated then a comparative cloth of plaster board with the residue and sodium citrate (Table 5) supplying the average voltage, standard deviation and coefficient of variance and a drying time of 8 and 18 days.

Table 5 - Influence of increased cure time.

Gypsum + Residue + Citrate	8 days	18 days
A. R. G. (MPa)	>0,17	>0,17
S. D. (MPa)	0,03	0,03
C. V. (%)	17	20

A. R. G. – Average Resistance of Grip; **S.D.** - Standard Deviation; **C.V.** - Coefficient of Variation.

Therefore, although the drying time increases by 10 days, the standard deviation is retained and average bond strength is not changed (> 0,17 MPa).

CONCLUSIONS

To the mixtures studied, the addition of gypsum residue with handle retardant additive influences the pulp consistency and behavior of adhesion.

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The coefficient of variation and the tensile bond strength is close to the acceptable to the plaster mix, and residual citrate. It can be inferred also that from the 8th day, there was no change in the adhesive strength of the plaster mortar with citrate.

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