

## Article

# Impact Resistance of Rendering Mortars with Natural and Textile-Acrylic Waste Fibres

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**Abstract:** Renders should have an adequate resistance to impacts, since they must protect the substrate. The use of fibres may enhance the energy absorbed when the mortars are submitted to an impact load, which contributes to postpone the first crack, and control its propagation and width. In this study, the impact strength was measured by a falling mass from different heights. The cracking pattern and the impact energy for the appearance of the first crack and until failure were evaluated. An artificial accelerated ageing test was also performed, and the impact resistance was analysed before and after ageing. In order to analyse the effects of recycled fibres, wool, coir, flax and textile-acrylic waste fibres were used as reinforcement in cement and cement-lime mortars. The results indicated that the fibres' addition significantly improved the impact energy of the rendering mortars in comparison with the reference mortars. Concerning the crack patterns, the recycled fibres prevented the opening or the growth of the cracks, before and after ageing. This effect is mainly due to the fibre's bridge mechanism, due to crossing the open cracks and hindering their propagation. The fibres' type, length and volume fraction have influenced the mortars' performance in terms of impact resistance. Textile-acrylic fibres waste presented the best performance by comparison with the natural fibres used.

**Keywords:** impact strength; fibre-reinforced mortars; natural fibres; recycled fibres; sustainability; render



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## 1. Introduction

An exterior coating should be resistant to impact, absorbing the energy produced in the impact without cracking and maintaining its performance. In general, mortars present a brittle behaviour, which makes it harder for the render to withstand the repeated impacts. One of the solutions to improve the capacity of energy absorption of rendering mortars is the addition of fibres in the mix. The impact strength of the composites is usually measured by two different methods, which assess their performance regarding the impact load. One test evaluates the impact on a vertical substrate with a pendulum and the other is applied to a horizontal substrate with a falling mass from different heights.

Previous works analysed the effect of fibres waste on the impact strength of the composites [1–7]. According to Brazão Farinha et al. [1], the use of fibres increases the impact resistance of the mortars, since the cracks in the fibre-reinforced mortar are narrower and more distributed in comparison to the brittle failure of the reference mortar. The authors highlighted that analysing the cracking pattern provides a better understanding of the render's deformability. Ramakrishna and Sundararajan [4] incorporated four natural fibres: coir, sisal, jute and *Hibiscus cannebinus*, with different fibre contents of 0.5%, 1.0%, 1.5% and 2.5% (by cement weight) and three lengths: 20 mm, 30 mm and 40 mm. The authors reported that the fibre-reinforced mortars presented an increase in impact resistance up to 18 times that of the reference mortar. The results show that this increase in impact resistance of the mortar depends on the type of natural fibre, fibre content and length.

Hwang et al. [6] and Pereira et al. [7] also investigated the impact strength of natural fibres in cement mortars. It was found that long fibres and a greater fibre content increased the impact resistance. This was attributed to the interlocking of the fibres in the cement matrix, which is related to their higher load-carrying capacity in the cementitious matrix. Therefore, fibre-reinforced mortars allow more deformability and energy absorption. Another finding was reported by Araya-Letelier et al. [8]; the authors incorporated pig hair fibres in cement mortars and the results indicate that the matrix supports the impact load without any contribution of the fibres before cracking occurs. However, after the cracking occurs, the fibres enabled the matrix to withstand the impact load without crack propagation.

In this study, the impact resistance was evaluated through a hard mass shock from a given height followed by the observation of the degradations caused by the render applied on the substrate. This test evaluates the effective capacity of absorbing damage of mortars [9]. It is well known that the addition of fibres in cementitious composites increases the amount of energy absorbed and dissipated, which postpones the first crack and its propagation [4]. Several effects were measured during the impact test. The energy required for the appearance of the first crack until failure, the number of hits to crack and propagation of the crack through the sample in repeated impact tests and the analysis of the dimensions and perforation deepness of the damages caused after loading.

The main novelty of this work is to assess the impact resistance of natural and textile-acrylic fibres waste in rendering mortars produced with two different matrices. No study of binary binder rendering mortars with natural fibres waste has been found in the literature. For this purpose, four fibres were used, namely wool, coir, flax and textile-acrylic, and two binders: cement and cement plus air-lime. The global characterization of these mortars was already reported in previous researches [10–14].

## 2. Materials and Methods

This research was intended to evaluate the impact resistance of rendering mortars with incorporation of natural and textile-acrylic waste fibres. Four waste fibres were tested and are presented in Figure 1. These fibres were waste from different industries located in Portugal. The natural fibres used were wool, coir and flax. Wool fibres were obtained from the waste not suitable for clothing industry after shearing of sheeps (*Burel Factory TrendBurel Lda*). Coir fibres were obtained through a Portuguese insulation company as the waste of coir panels (*Amorim Cork Insulation*). Flax fibres were rejects from the agriculture industry not usable for the clothes industry. Textile-acrylic fibres came from textile industry and are wastes from the last process of the fabric production to clothing market (*Fisipe Synthetic Fibre Portugal, SA*). Textile-acrylic fibres are composed of thinner acrylic fibres assembly waste. Previously to the mix, the fibres were manually cut into pieces of lengths of 15 mm and 30 mm and blown with compressed air to improve dispersion in order to disentangle the fibres. The fibres lengths were chosen according to the previous studies found in the literature.



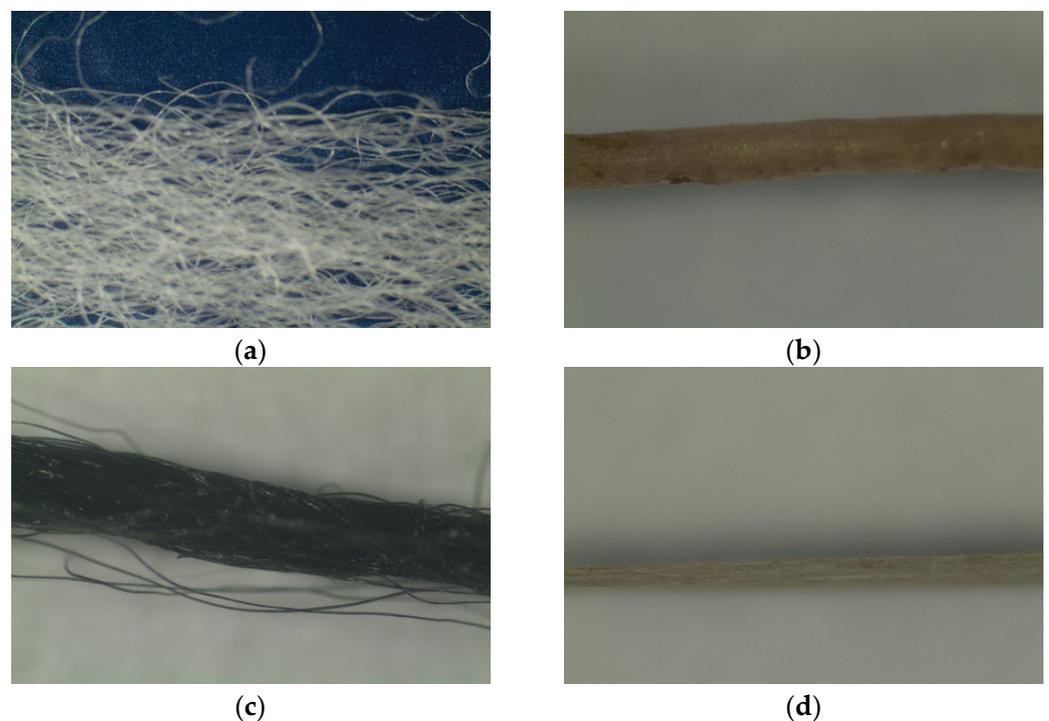
Figure 1. Cont.



**Figure 1.** Fibre's waste used: (a) wool fibres, (b) coir fibres, (c) textile-acrylic fibres and (d) flax fibres.

The mortars were produced with two binders, cement CEM II/B-L 32.5N, according to EN 197-1 [15], and calcium hydrated lime powder—air-lime class CL80-S, according to EN 459-1 [16]. Natural sand previously washed, calibrated and sieved for a required size distribution was used. The aggregate used was natural sand from a Portuguese company (*Areipor S.A.*).

In order to characterize the fibres at a microscale, microscopic observation was performed using an Olympus SZH-10 optical microscope. The micrographs are shown in Figure 2. From these micrographs, the diameter, shape and surface texture of the fibres could be observed. Among the natural fibres, wool fibres presented the smallest diameter, approximately 30  $\mu\text{m}$ , followed by flax fibres (50  $\mu\text{m}$ ). It was possible to isolate a single flax fibre, whereas the wool fibres were kept clustered. Coir fibres presented a diameter of around 180  $\mu\text{m}$ . Textile-acrylic fibres were incorporated as a bundle of 407  $\mu\text{m}$  diameter. It was noted that the textile-acrylic fibres are composed of several thinner fibres, with a diameter of approximately 10  $\mu\text{m}$  each.



**Figure 2.** Micrographs: (a) wool fibres, (b) coir fibres, (c) textile-acrylic fibres and (d) flax fibres.

The aspect ratio of the fibres is presented in Table 1.

**Table 1.** Size of the fibres.

Fibre	Length (mm)	Diameter (mm)	Aspect Ratio (Length/Diameter) (mm/mm)
Wool	15	0.030	500
	30		1000
Coir	15	0.180	83
	30		167
Flax	15	0.050	300
	30		600
Textile-acrylic	15	0.407	37
	30		74

Mortars with two different volumetric proportions binder: aggregate were produced, namely cement mortars (1:4—cement: aggregates) and cement-lime mortars (1:1:6—cement: air-lime: aggregates). Different fibres' length and volume fractions were used. The ratios of the fibres' incorporation were 10% and 20% of the total mortar volume. These proportions were chosen based on the largest number of fibres that could be incorporated without jeopardizing the fresh state of the mortars, evidenced by trial applications of the mortar on a brick. Therefore, ten mortars were designed and identified, as shown in Table 2.

**Table 2.** Composition of the mortar's mixes.

Mortars	Fibres' Type	Cement (g)	Air-Lime (g)	Sand (g)	Water to Binder Ratio	Volume of Fibres Incorporated (%)	Fibres' Length (mm)
REF 1:4	-	487.8	-	2461.6	0.9	0%	-
W 3.0-10c	Wool	439.1	-	2215.4	1.0	10%	30
C 3.0-10c	Coir	439.1	-	2215.4	1.0	10%	30
F 3.0-10c	Flax	439.1	-	2215.4	1.0	10%	30
T 3.0-10c	Textile-acrylic	439.1	-	2215.4	1.0	10%	30
REF 1:1:6	-	304.8	176.8	2307.8	1.0	0%	-
W 1.5-20cl	Wool	243.9	141.4	1846.2	1.0	20%	15
C 1.5-20cl	Coir	243.9	141.4	1846.2	1.0	20%	15
F 1.5-20cl	Flax	243.9	141.4	1846.2	1.0	20%	15
T 1.5-20cl	Textile-acrylic	243.9	141.4	1846.2	1.1	20%	15

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

These mortars were selected from a wider range of mortars previously characterized in terms of fresh, hygric, mechanical and durability behaviour [10–14]. The best incorporation ratio and length were chosen for each fibre and binder.

In this work, the impact strength of the modified rendering mortars was assessed with a falling mass of 1 kg dropping onto a mortar surface from a height of 1 m, and then, an increment of 0.10 m to each drop. This impact test was based on the European Standard EN 477 [17] but adapted to mortars. The impact energy was quantified by the height for first crack initiation based on visual observation and for the ultimate failure. The crack patterns were observed and the recessed diameter resulting from each blow of the steel ball were quantified. In this test, the number of blows required for initiation of crack and failure are determined based on different zones of the specimens in order to better quantify the actual impact energy, thus not considering repeatedly blows on the same place. The artificial accelerated ageing procedure performed was adapted to EN 1015-21 [18]. The mortars were applied 2 cm thick on a ceramic brick. For the mortar's production, a fixed range value of  $140 \pm 5$  mm was chosen in the consistence flow table test, after an application on the brick.

The curing conditions of the mortars complied with EN 1015-11 [19]. The specimens were kept for 7 days after production at a temperature of  $20 \pm 2$  °C and relative humidity of  $95 \pm 5\%$ . After that, the relative humidity was reduced to  $65 \pm 5\%$ , until testing (28 days). The impact resistance was analysed by the impact energy generated by 1 kg mass falling repeatedly from different heights, as shown in Figure 3. The first crack and failure energy are recorded, and the diameter, width and depth of the dent in each specimen are measured. The test starts with a fall from 1 m of height, and at each fall 0.10 m is added to the height, until collapse is reached. The impact energy was calculated by multiplying the mass by the gravity acceleration and the falling height, for each height. The energy required for appearance of the first crack and for failure was quantified. The impact resistance of the mortars increases with the height at which the first crack and failure occur.



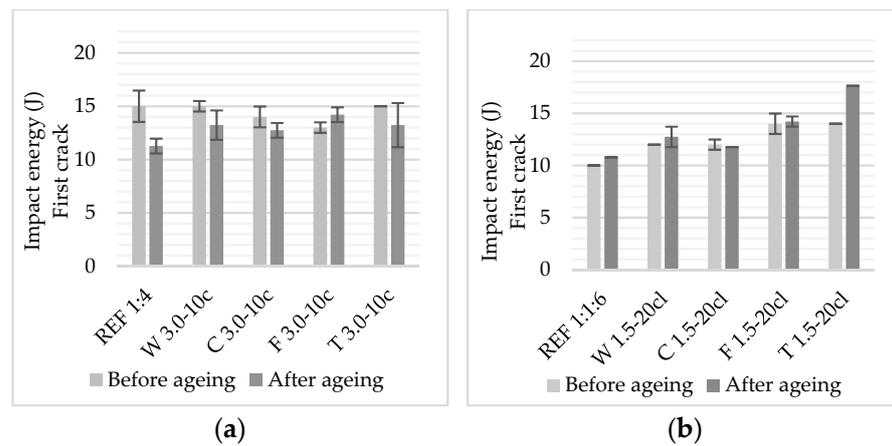
**Figure 3.** Illustration of the impact test.

The artificial accelerated ageing test performed consisted of eight heating–freezing cycles followed by eight humidification–freezing cycles and was previously described in more detail in Pederneiras et al. [11]

### 3. Results and Discussion

The impact energy analysed through the test was calculated from the falling mass on the render's specimens until the first crack and failure occurred. The impact resistance test was performed before and after accelerated ageing, in order to evaluate the effective capacity of the mortars to absorb damage caused by the impacts during their service life. The impact energy at the first crack appearance, before and after ageing, of the cement and cement-lime mortars is presented in Figure 4.

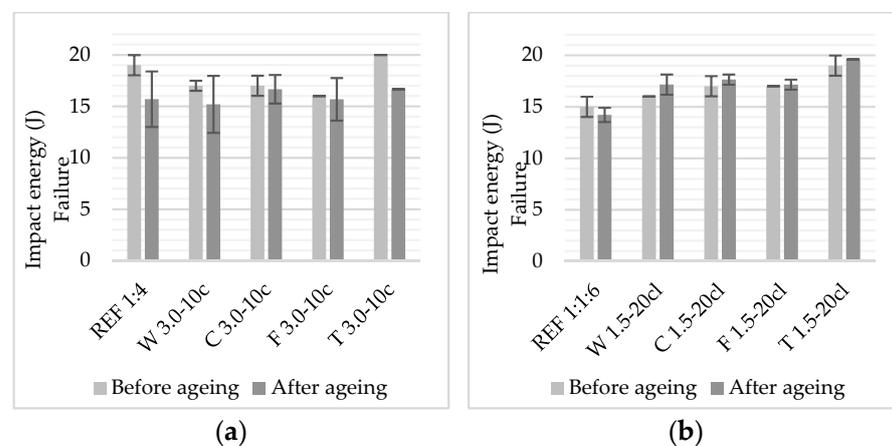
For cement mortars, it was noticed that the impact energy until the first crack arises, before ageing (at 28 days), was not affected by the addition of fibres. This result is in accordance with the trend of previous studies in the literature [3,8,9,20]. Therefore, for cement mortars at 28 days, the fibres seem not to contribute to withstand the impact load applied on the matrix before crack occurs. On the other hand, after the artificial ageing test, regardless of the type of fibre used, the impact energy for the first crack to appear in the fibre-reinforced cement mortars increased up to 18% in comparison with the reference mortar. This is attributed to the reduction of impact energy of REF 1:4, which became more brittle, and the first crack appeared earlier than in the modified mortars. It was evidenced that the fibres improve the mortars' performance after ageing, in terms of impact resistance, postponing the first crack's appearance.



**Figure 4.** Impact energy before and ageing at first crack of the mortars: (a) cement mortars and (b) cement-lime mortars.

Regarding the cement-lime mortars, the effect of the use of fibres on the impact energy for the first crack occurrence is clearly amplified, before and after ageing. In general, the impact energy at first crack appearance increased after the ageing cycles. The textile-acrylic fibre-reinforced mortar obtained the highest increase when compared to REF 1:1:6, of 64% in impact energy at first crack. These results indicate that the fibre-reinforced cement-lime mortars presented higher impact energy before the first crack occurs.

The impact energy until failure, before and after ageing, of the cement and cement-lime mortars is presented in Figure 5. For cement mortars, the addition of fibres did not present significant changes, except for the mortar reinforced with textile-acrylic fibres, which showed an improvement of impact resistance, both before and after ageing. A reduction of the impact energy at failure after ageing was observed on all the mortars, which seemed to become more brittle after ageing. On the other hand, for cement-lime mortars, the impact energy at failure did not present any significant changes after ageing. REF 1:1:6 slightly decreased the impact energy after ageing, which suggests some embrittlement of the REF 1:1:6 mortar as an ageing effect. Furthermore, for fibre-reinforced mortars, a slight increase in impact energy at failure was observed. The highest value was obtained for the textile-acrylic fibre-reinforced cement-lime mortar, which increased approximately 43% relative to the reference mortar, after ageing. In fact, the fibres act as bridging mechanism across the cracks, which enhance the deflection capacity without failure and improve the mortars' ductility.



**Figure 5.** Impact energy before and after ageing at failure of the mortars: (a) cement mortars and (b) cement-lime mortars.

In addition to the impact energy at first crack appearance and at failure, before and after ageing, the dent in the specimens created by the falling mass was measured. The dent diameter and the crack width for every drop height of the mass were analysed. The first crack's width and dent diameter, for each mortar, are presented in Table 3. Before ageing, the diameter of the dent was similar for all mortars. After ageing, a decrease in the diameter in the reference mortar was noticed, which is an indicator of higher stiffness.

Table 3. Impact dent characteristics and cracking width.

Mortar	Before Ageing						After Ageing					
	Diameter of Dent (mm)		Depth of Dent (mm)		Crack Width		Diameter of Dent (mm)		Depth of Dent (mm)		Crack Width	
	First Crack	Failure	First Crack	Failure	First Crack	Failure	First Crack	Failure	First Crack	Failure	First Crack	Failure
REF 1:4	14.64	16.27	1.02	1.16	0.20	1.00	11.44	13.69	0.98	1.09	0.20	1.00
W 3.0-10c	13.65	17.94	0.91	1.74	0.08	0.75	13.04	13.65	0.94	0.88	0.05	1.00
C 3.0-10c	13.88	16.76	1.05	1.25	0.08	0.50	13.35	16.24	0.56	1.42	0.05	0.30
F 3.0-10c	12.77	15.41	0.99	1.48	0.10	0.75	13.72	14.55	1.00	0.94	0.05	0.50
T 3.0-10c	14.12	17.48	1.09	1.55	0.10	0.50	13.31	15.08	0.92	1.06	0.05	0.30
REF 1:1:6	14.13	16.46	0.99	1.41	0.10	0.75	12.60	15.16	0.67	1.08	0.10	1.00
W 1.5-20cl	14.84	16.68	1.23	1.53	0.08	0.45	13.79	17.09	1.17	1.64	0.08	0.45
C 1.5-20cl	14.51	20.84	1.28	2.19	0.08	0.70	13.76	17.31	0.89	1.47	0.08	1.00
F 1.5-20cl	15.00	21.52	1.11	2.16	0.05	0.35	12.12	15.65	0.84	1.48	0.08	0.50
T 1.5-20cl	17.05	21.86	1.60	2.10	0.08	0.30	16.40	18.17	1.40	1.55	0.05	0.10

Regarding the cracks' width, it is clear that fibres prevent their opening and growth, before and after ageing. After ageing, the first crack's width of the fibre-reinforced mortars decreased when compared to before ageing, which is in accordance with the impact energy at first crack after ageing, indicating an increase in deformability found in the mortars with fibres. After the artificial accelerated ageing test, the first crack's width of all the modified mortars fell by 75% when compared to the reference cement mortar.

From the results, it was found that the fibres' addition increased the dent diameter, which can suggest that the modified mortars are more deformable when compared to reference mortars. Regarding the crack width, it can be seen that both before and after ageing the fibre-reinforced mortars presented a lower crack width than the reference mortars.

After the artificial accelerated ageing test, the first crack's width of all modified mortars decreased when compared to the REF's. Figure 6 shows the resistance to impact at first crack, before and after ageing, of the reference cement mortar. It was observed that, after ageing, the first crack occurs for smaller height of the drop of mass, which indicates an embrittlement of the reference mortar. This brittle behaviour of the REF 1:4 mortar was also observed in the resistance to impact at failure, as shown in Figure 7.

In fact, cracks significantly widened, completely disintegrating the mortar and a reduction in impact strength is noted when compared to the reference cement mortar before ageing (18.6 J vs. 15.7 J). It was observed that, for the mortars without fibres, regardless of the binder used, the first crack appeared for small load heights and failure occurred in a brittle mode. The reference mortars presented a single crack with a large width that crossed the entire specimen.

On the other hand, the mortars reinforced with fibres did not significantly change their properties with ageing. For instance, Figure 7 presents the resistance to impact at failure of the textile-acrylic fibre-reinforced mortar, before and after ageing, which show similar behaviour. It is possible to note that the fibre-reinforced mortars presented a completely different failure pattern. It was noticed that, at failure, the modified mortars presented a more distributed crack pattern with low widths, which suggests a more ductile behaviour.

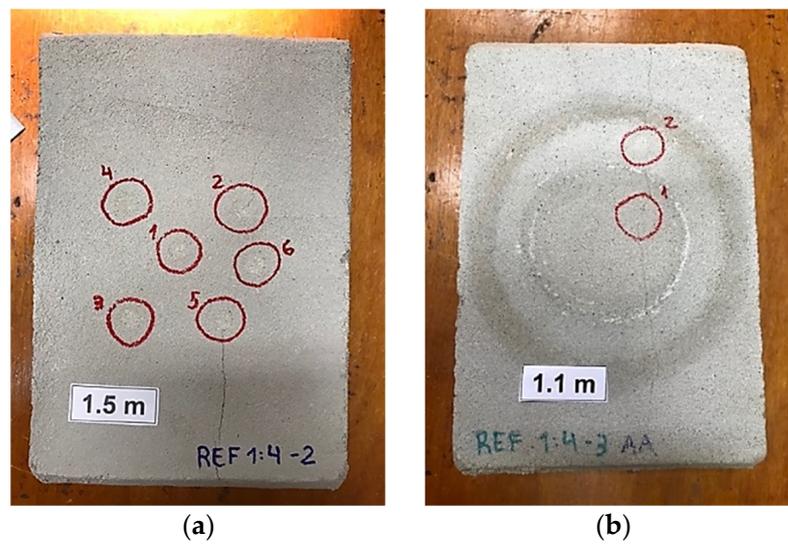


Figure 6. Resistance to impact at first crack: (a) before and (b) after ageing—REF 1:4.

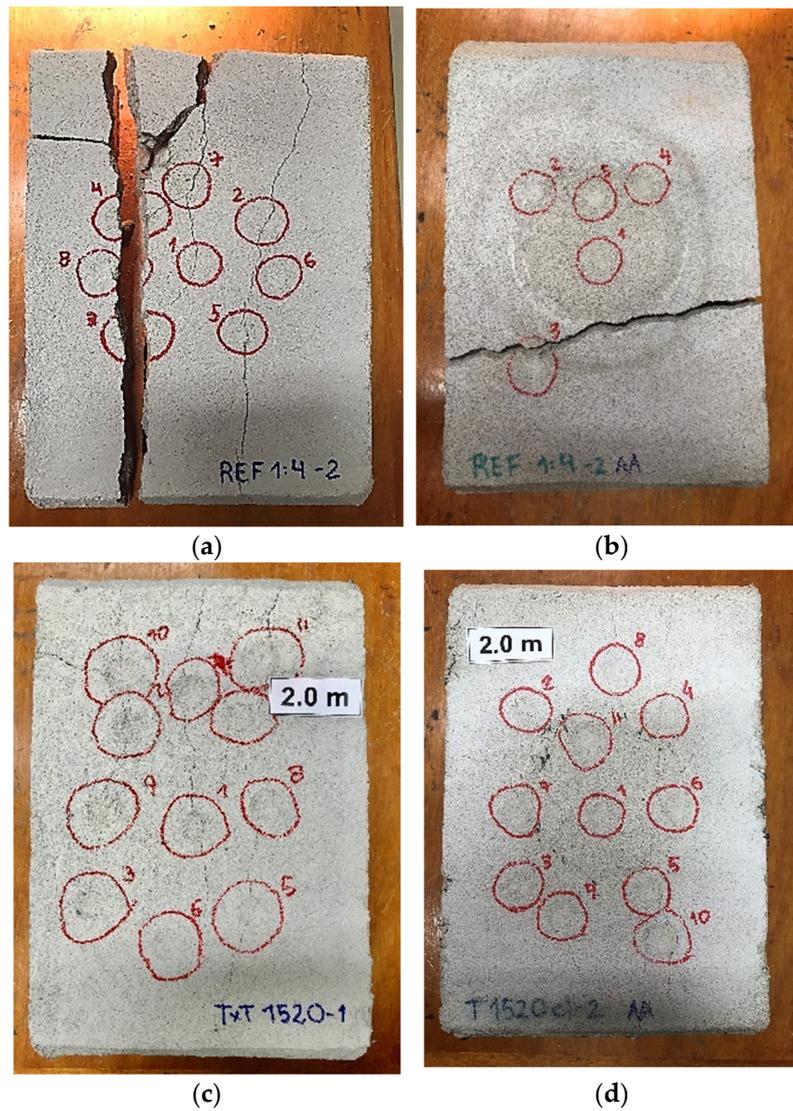
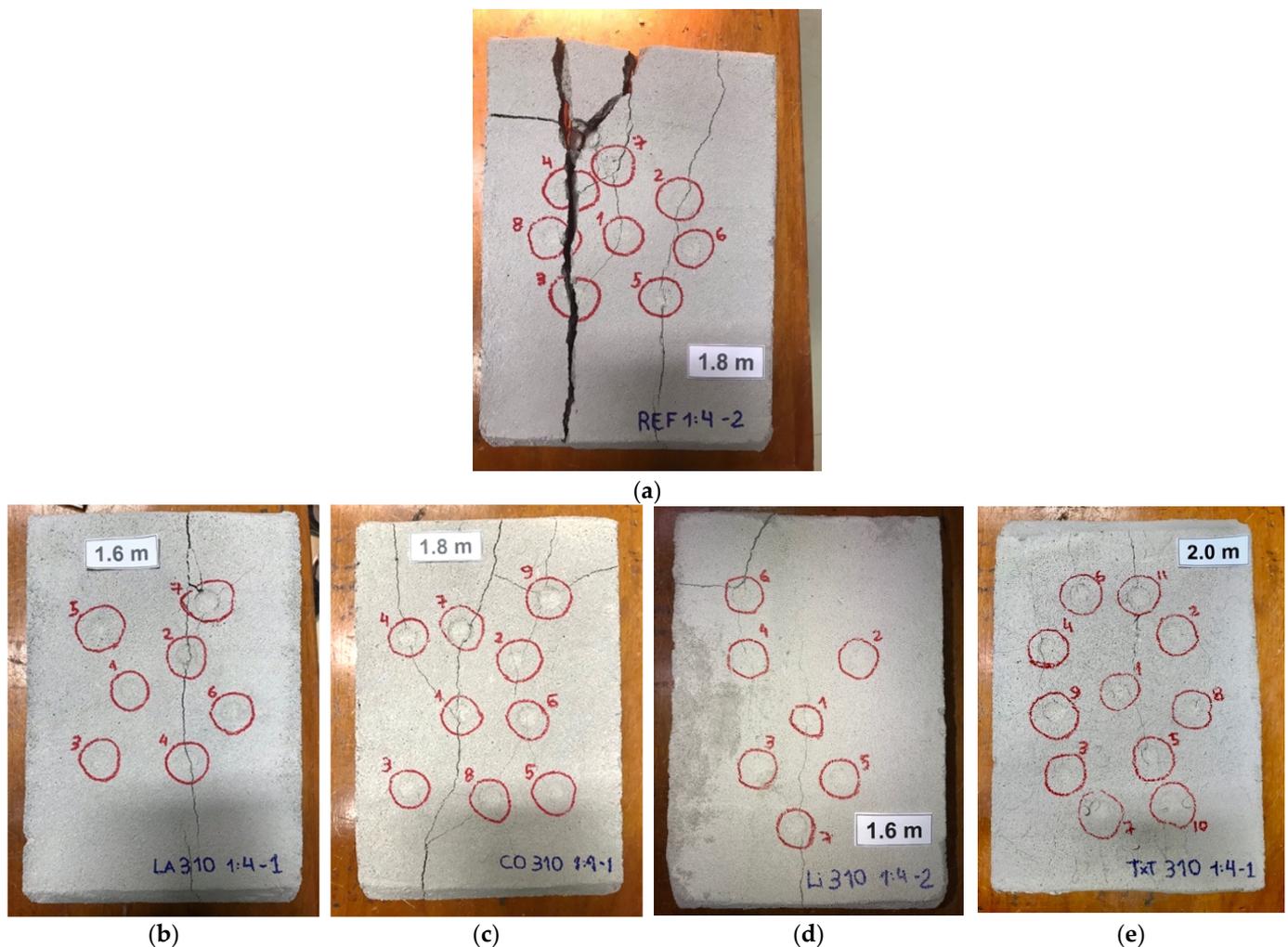


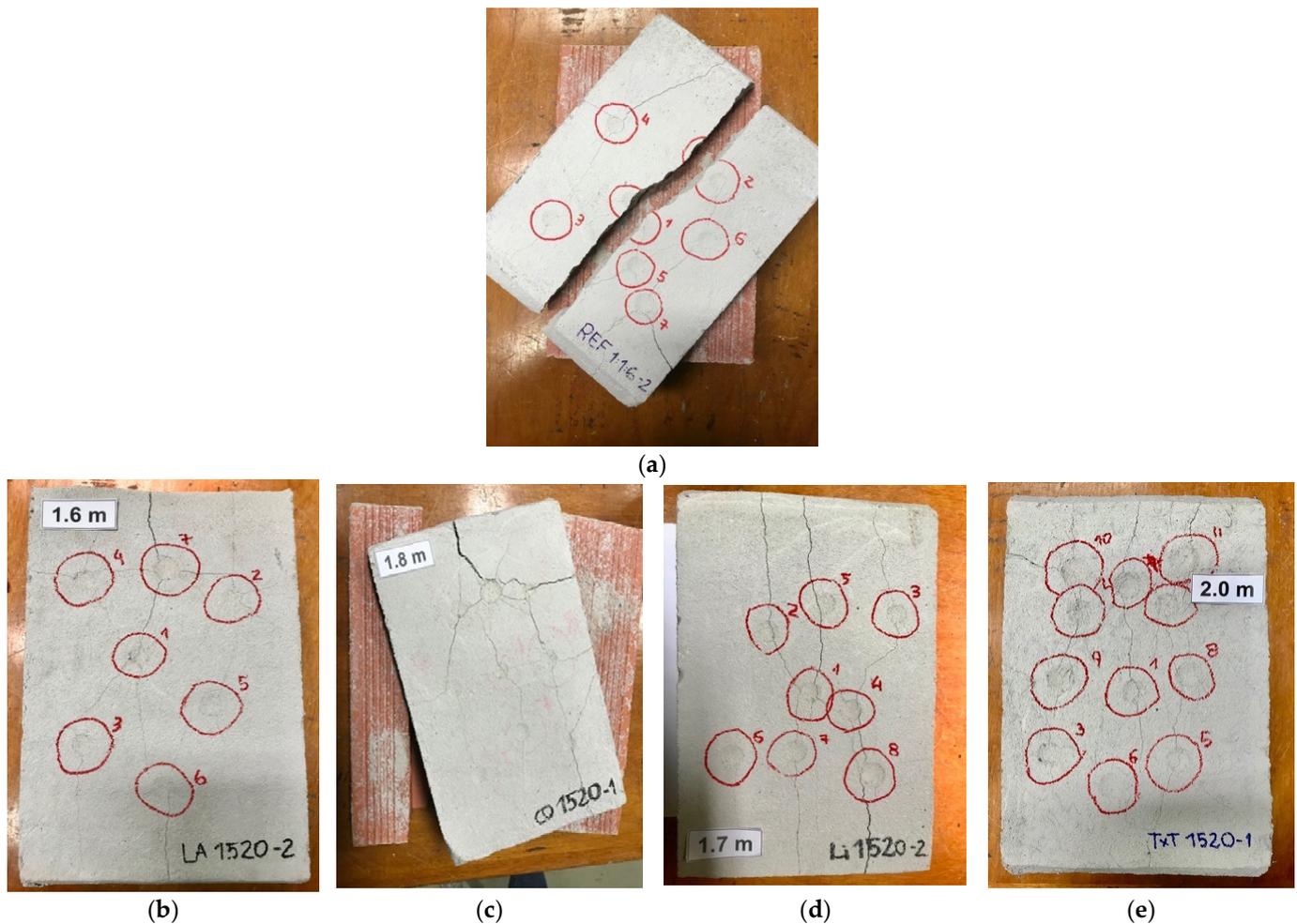
Figure 7. Resistance to impact (failure): REF1:4 mortar (a) before ageing and (b) after ageing; and T 1520cl mortar (c) before ageing and (d) after ageing.

Figures 8 and 9 present the crack pattern of the mortars analysed: cement and cement-lime mortars, respectively. In all the modified mortars, well-distributed cracks, with small width, were observed. These failure patterns are characteristic of a ductile material. Among the modified mortars, T 3.0-10c presented the best impact resistance. Some specimens after ageing during the impact test did not achieve failure, i.e., it is possible to note that the brick (substrate) broke before the render, which indicates a good impact resistance of the mortar. The increase in impact resistance of the mortars with the incorporation of fibres was also reported in the literature. Ramakrishna and Sundararajan [4] reported a review of the studies on the impact strength characteristics of the natural fibre-reinforced composites.

Fujiyama et al. [21] and Pereira et al. [22] found that the use of sisal fibres in cement mortars considerably increased their impact resistance. The authors pointed out that longer fibres presented better results when compared to shorter ones. This increment was attributable to the higher energy absorption of the mortars with fibres. The load-carrying capacity is improved by the fibres, which contributes to a more deformable mortar. Muda et al. [23] observed that the addition of kenaf fibres in concrete significantly increased their impact resistance as the fibres' diameter increased.



**Figure 8.** Crack pattern of cement mortars, before ageing, at failure: (a) reference mortar, (b) wool fibre-reinforced mortar, (c) coir fibre-reinforced mortar, (d) flax fibre-reinforced mortar and (e) textile-acrylic fibre-reinforced mortar.



**Figure 9.** Crack pattern of cement-lime mortars, before ageing, at failure: (a) reference mortar, (b) wool fibre-reinforced mortar, (c) coir fibre-reinforced mortar, (d) flax fibre-reinforced mortar and (e) textile-acrylic fibre-reinforced mortar.

Ramakrishna and Sundararajan [4] analysed the impact strength of mortars with coir, sisal, jute and *Hibiscus cannebinus* fibres with different volume fractions and lengths. The authors reported that the natural fibre-reinforced mortars did not break into distinct pieces, whereas the reference mortar specimen broke into small pieces. Coir fibre-reinforced mortars presented the highest impact resistance as the fibre content and length increased. The impact resistance increases with an increase in the fibre's length, due mainly to the interlocking of the fibres in the cement matrix. Therefore, the addition of natural fibres increased the ductility of the mortars.

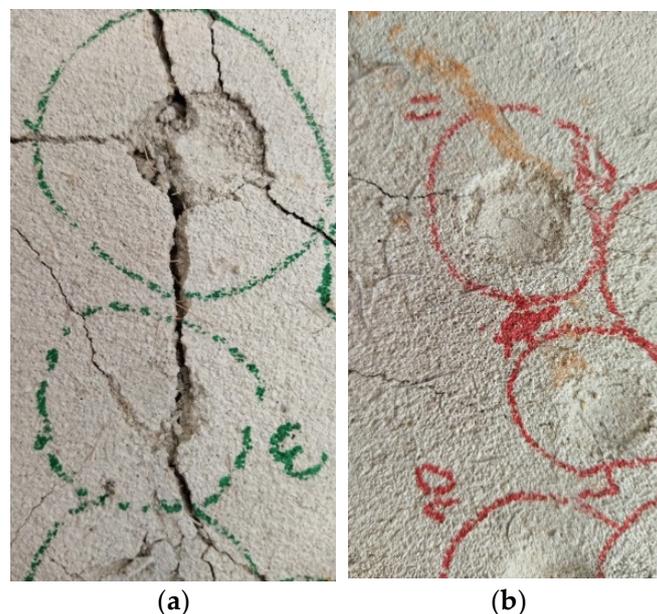
Araya-Letelier et al. [9] also found an increment in impact resistance with the incorporation of pig hair in cement mortars, i.e., these mortars enhanced their capacity of absorbing damage. Moreover, the post-cracking behaviour of the fibre-reinforced mortar significantly improved the energy absorbed beyond initial crack formation and at failure. Hwang et al. [6] found an improvement of impact resistance when coir fibres were added in cement mortars, mainly due to the impact energy that was absorbed by them. Additionally, the authors reported that the coir fibres distributed the stresses caused by the drop weight, whereas the mortar without fibres presented a brittle behaviour and broke into pieces. Mansur and Aziz [5] also indicated an increase in impact strength of mortars with jute fibres.

Alongside the studies on natural fibres in cement mortars, Brazão Farinha et al. [1], Araya-Letelier et al. [8] and Xuan et al. [2] analysed the impact resistance of mortars with recycled synthetic waste fibres. In the previous studies, the incorporation of these fibres

enhanced the impact resistance. In fact, the fibres improved the impact energy at first crack and at failure of the mortars. Brazão Farinha et al. [1] reported that the use of textile-acrylic fibres waste increased the impact energy of the cement-based mortars up to 18% and 7%, at first crack and until failure, respectively. The authors also compare the crack pattern and the fibre-reinforced mortars presented lower width and more distributed cracks.

Despite the previous studies, there is still a lack of investigation on rendering mortars with rejects of agricultural and textile-acrylic industry. Therefore, the findings of this paper contribute to the use of waste by maximizing the percentage of incorporation. Usually, studies investigated low volume of fibres from 0.5% and 2% by volume [24]. Thus, in this work a higher fibre content was evaluated in order to incorporate the maximum value and not to jeopardize the mortars' workability.

In order to visualize the cracks widths with fibres, Figure 10 presents the cracks openings. It is clear the coir and textile-acrylic fibres crossing the cracks. However, wool and flax fibres are not visible to the naked eye.



**Figure 10.** Fibres' cross section (a) coir fibre cement-lime mortar and (b) textile-acrylic fibre cement-lime mortar.

The width of the cracks in the fibre-reinforced cement mortars does not extend and spread as the reference mortars. The reduction of crack's width in the cement-lime mortars with fibres was smaller than in mortars with cement only. It could also be due to the fibres' length, since for impact strength tests the cement mortars were prepared with 3.0 cm long fibres and the cement-lime mortar used 1.5 cm long fibres. Nonetheless, it was observed that all the mortars with fibres presented well-distributed cracks with smaller width when compared to the control mortars.

Regarding the binders used, it can be concluded that, in general, the cement mortars presented a higher impact energy for first crack appearance and failure in comparison to the mortars with binary binder. However, the contribution of the fibres' incorporation was more evident in mortars with cement and air-lime binary binder. The increase in impact energy was more significant when higher volume of fibres was added. Therefore, it is evidenced that the cement-lime mortars with fibres deform more and absorb more energy until first crack and failure occurrence when compared to the reference mortar.

Another finding of this study is that the use of fibres waste reduced the embrittlement caused by the accelerated artificial ageing test, since unreinforced mortars presented a worse impact behaviour after ageing, which was not observed in the fibre-reinforced mortars.

#### 4. Conclusions

This research evaluated the impact resistance of cement-based mortars and cement-lime mortars with incorporation of four fibres waste, namely wool fibre, coir fibre, flax fibre and textile-acrylic fibre, before and after ageing. The following conclusions can be drawn:

- The impact energy was higher for the fibre-reinforced mortars, both at first crack appearance and at failure, before and after ageing. All the fibre-reinforced mortars are more able to deform under some incidence of load, which indicates some ductility. The increment of impact energy for first crack appearance was higher for cement-lime mortars with the use of fibres than in mortars with cement only;
- Concerning the cement mortars, they did not present significant differences in the impact strength of the mortars. However, the cracks' width of the modified mortars is lower when long fibres (3.0 cm) were used, which suggests that the fibres may cross the cracks opening and hinder their propagation. On the other hand, the cement-lime mortars with fibres showed an increase in the impact strength and not that evidence in the crack widths. From the crack patterns evaluated, it was found that the fibres waste in rendering mortars improved their impact behaviour, since the cracks were more distributed and presented lower width, whereas the unreinforced mortars showed a brittle failure with cracks of greater width;
- Within the natural fibres used, the incorporation of coir fibres in cement-based mortars presented the best performance considering the impact energy and the dent characteristics. For the cement-lime mortars, the use of flax fibres showed better behaviour. Nonetheless, among all the fibres, textile-acrylic fibres were the ones that presented the best performance in terms of impact resistance of the mortars. This could be probably to the fibre composition, since there are several thinner fibres bonded together;
- From the artificial ageing process, it was found that the cement-lime mortars with fibres did not present any significant changes with ageing. The cement-based mortars were more affected. However, REF 1:4 presented the highest drop of impact energy when comparing before and after ageing, whereas the cement mortars with fibres presented a slight reduction.

Overall, it can be concluded that the use of recycled fibres is feasible to increase the renders' performance in terms of cracking susceptibility and impact resistance, by incorporating a high volume of fibre content without compromising the mortars application. This contributes to the development of more sustainable buildings materials, avoiding the use of virgin fibres, providing a proper disposal to the waste, and considering cost-effective solutions, since the fibres used in this work were rejects from agricultural and textile-acrylic industry. Therefore, the incorporation of these wastes in renders could be an environmentally friendly and low-cost solution for their reutilization.

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