Reutilization of Leather Residue by Incorporation in Bricks

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Abstract

Leather strips is one by-product of the footwear industry. Due to high chromium content, this leather residue can be regarded as a threat to the environment, particularly if no care is taken with its disposal. With the incorporation of this residue into ceramic products, it is possible to neutralise the chromium toxicity. In a laboratory study, the authors produced prismatic bricks using clay from the region, incorporating 1, 3 and 5 mass-% of leather residues. The bricks were tested regarding their flexure, compression and leaching. The results showed that chromium toxicity disappeared in the bricks. The mechanical tests showed a decrease in strength for the specimens with leather residue. However, as bricks were lighter and more porous, it can be expected that they show better thermal insulation.

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1 Introduction

The reutilization of by-products of all industries is recommended to minimise their disposal and treatment. In the case of leather residues, their possible toxicity increases the problems. The introduction of these residues to the raw material of ceramic products was investigated in this study. To have a homogeneous mixture, a mechanical mixer was used. Subsequently, small bricks were made by filling up steel moulds. In order to develop some compactness, a spatula was used to apply pressure in the material. Industrially, other methods such as extrusion can give better results [1]

Industrial-scale drying and firing processes were simulated in the laboratory. Drying [2, 3] and firing [4] are very important phases in ceramics production. If drying and firing are not carried out correctly and slowly, the products can develop cracks [5]. When the small bricks were completely fired, the tests were started. Firstly, the bricks were tested to determine whether they exhibited the characteristic of extraction procedure toxicity [6]. Secondly, the possibility of bricks utilization as construction material in all the traditional applications [7] was analysed.

2 Bricks Production

Clay from the region was used for the bricks production. 1, 3 and 5 mass-% of leather residues were incorporated into the clay. Some control specimens, without any incorporation, were shaped. In order to have the same plasticity, the quantity of water was different for each incorporation (Table 1). The mixture was made in a mechanical mixer until it became a homogeneous paste. Afterwards, steel moulds were filled up with a help of a spatula. To obtain better compactness, some pressure was exerted with the spatula.

The bricks had a prismatic form with the dimensions of 4 cm x 4 cm x 16 cm. Four samples of each incorporation were shaped. The brick samples were removed from the moulds and drying was performed in five stages in a kiln for 48 h at a temperature range from 30 to 100 °C. Firing was performed in a muffle kiln where the highest temperature (1000 °C) was reached at approximately 12 h and the bricks were maintained at this temperature for 1 h. After firing, specially in the bricks with 3 and 5 mass-% of residues incorporation respectively, some exterior pores were observed (Figs. 1 and 2), resulting from residues carbonisation.

3 Leaching Tests

Leaching tests were performed in accordance with [8]. The fired bricks were ground so that the material could pass through a 9.5 mm sieve which was then subjected to the extraction procedure. The samples obtained after filtration were analysed to determine total chromium (Cr_{total}) and hexavalent chromium [Cr(VI)]. No significant concentrations were found (Table 2).

Since low concentrations were obtained in these samples, no tests were made on the bricks with 1 mass-%

Table 1
Quantity of mixing water in the bodies

Leather Residue Incorporation [mass-%]	Mixing Water [mass-%]
0	26.0
1	29.7
3	30.2
5	30.2

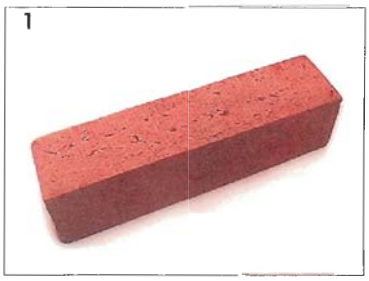

Fig. 1
Specimen without residue incorporation

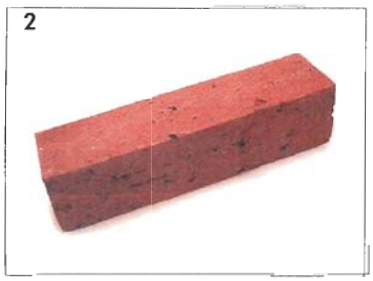

Fig. 2
Specimen with 3 mass-% incorporation

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Table 2
Leaching results for the tested bricks and limit values for harmful wastes [9]

Leather Residue Incorporation [mass-%]	Cr_{total} [mg/dm³]	Cr (VI) [mg/dm⁻³]
0	0.02–0.04	ND*
3	≤ 0.03	ND*
5	≤ 0.04	≤ 0.01
Harmful waste	–	0.1–0.5

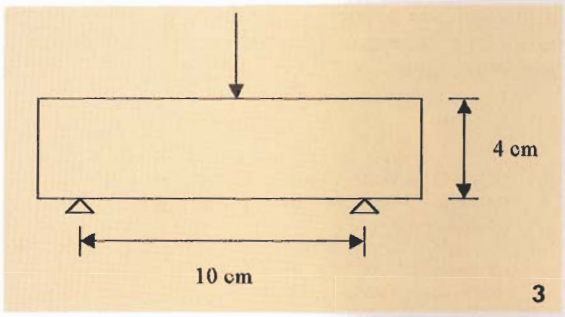
* Not Detected

Table 3
Total chromium concentrations for the leather residues and brick material

Leather Residue Incorporation [mass-%]	Cr_{total} [mg/dm³]	Cr_{total} [g/kg]
0	3	0.12
3	19	0.76
5	28	1.12
Leather residue	955	19.10

Table 4
Modulus of rupture and compressive strength of the bricks (average values)

Leather Residue Incorporation [mass-%]	Modulus of Rupture [MPa]	Compressive Strength [MPa]
0	2.52	10.65
1	1.77	8.10
3	1.81	5.88
5	2.08	6.38



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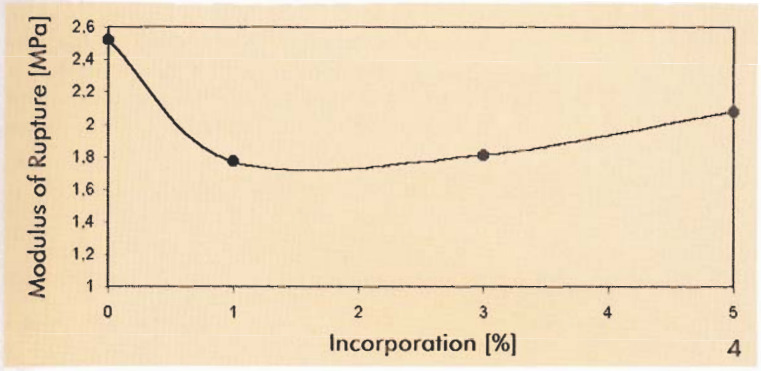

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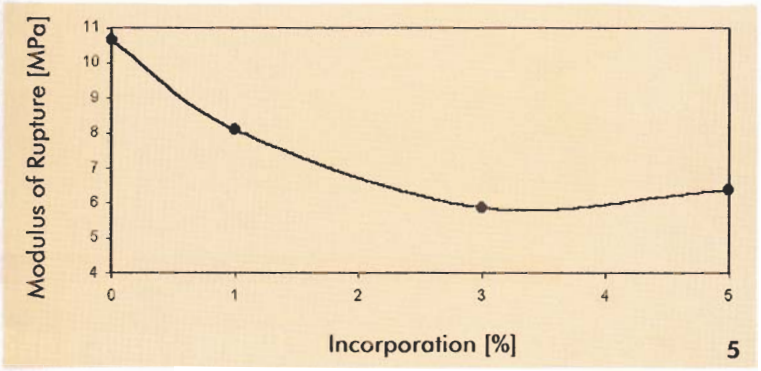

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incorporation. These results show that chromium compounds are basically immobilised in the clay matrix. On the other hand, in view of these results, the possibility of chromium losses during firing occurred. So, determinations of total chromium (Cr_{total}) in the brick material and in the leather residues were carried out (Table 3). These results allow the rejection of the possibility of chromium volatilisation during firing. The chromium concentration in the brick material was never inferior to the expected value regarding the concentration in the raw material.

4 Mechanical Testing

Flexure and compressive tests were made in accordance with [9]. The flexure test was a three-point one (Fig. 3). The compressive tests were carried out in the two halves of the original prism after failure by flexure. As the surfaces were plane and without any depressions, no capping had to be done.

The results are presented in Table 4. With 1 mass-% residue incorporation, a decrease of 30 % in the modulus of rupture and 22 % in the compressive strength was found. The decrease of compressive strength is more significant for 3 and 5 mass-% residue incorporation, i.e. around 45 %.

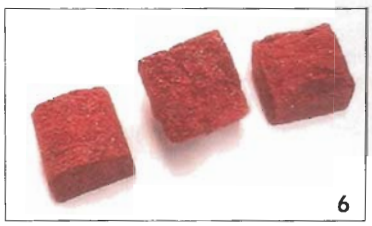
For the modulus of rupture, after the minimum of 1 mass-% residue incorporation, the values increase with the quantity of leather residues. Figs. 4 and 5 show the variation of the modulus of rupture and of the compressive strength with the percentage of incorporation.

The observation of the specimens' surface of fracture after the compressive tests shows that the quantity of pores (black areas) increase with residue incorporation (Figs. 6–8). The black areas resulted from the carbonisation of residues.

5 Other Tests

Before mechanical testing, the weight and the precise dimensions of the specimens were determined. With these values, the density was determined, the results of which are presented in Table 5. The density decrease varies from 6 % for the bricks with 1 mass-% residue incorporation to 12 % for the highest residue incorporation.

Efflorescence tests were made in accordance with [10]. Two half specimens with 0 mass-% incorporation and two half specimens with 3 mass-% residue incorporation were used. No tested specimens showed efflorescence.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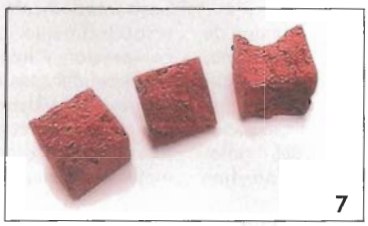
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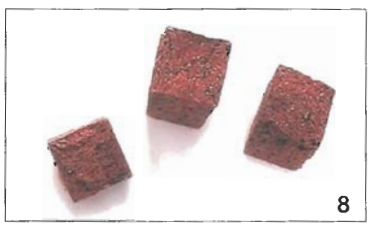
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Fig. 3
Flexure test on standard bricks

Fig. 4
Variation of modulus of rupture with the amount of leather residue incorporation

Fig. 5
Variation of compressive strength with the amount of leather residue incorporation

Fig. 6
Specimen slices without residue incorporation after firing

Fig. 7
Specimen slices with 1 mass-% residue incorporation after firing

Fig. 8
Specimen slices with 5 mass-% residue incorporation after firing

Table 5
Weight, volume and density of the bricks (average values)

Leather Residue Incorporation [mass-%]	Mass [g]	Volume [cm³]	Density [g/cm³]
0	360.8	213.7	1.7
1	342.5	207.9	1.6
3	325.1	212.3	1.5
5	320.8	212.3	1.5

6 Conclusion

The incorporation of leather residues into the raw material used to produce bricks is possible. Losses of chromium [Cr (III) + Cr (VI)] on leaching or volatilisation during firing were not verified. However, some decrease in the values corresponding to the mechanical properties (modulus of rupture and compressive strength) were noted. Therefore, it is necessary to limit residue incorporation to around 1 mass-% according to the clay amount. As the residues are very light, this represents a reasonable volume.

Incorporation decreases the density of the bricks. This is due to the increase of porosity because the residues carbonise during firing, resulting in big pores. This does not pose a problem because the perforated bricks show good thermal insulation and sound absorption [11]. So, with the incorporation of the leather residues there is some loss of mechanical strength but there is a gain in thermal and sound properties of the bricks. It is a reasonable assumption that these bricks can be used in partition walls.

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Kurzfassung/Résumé/Resumen

Die Wiederverwertung von Lederabfällen in Ziegelmassen

Lederstreifen sind ein Nebenprodukt der Schuhindustrie. Aufgrund des hohen Gehaltes an Chrom kann man dieses Nebenprodukt als umweltschädlich, besonders im Falle einer nicht ordungsgemäßen Entsorgung, betrachten. Durch die Beimengung dieses Abfalles in keramische Massen kann die Toxizität des Chromes behoben werden. Innerhalb einer Laborstudie haben die Autoren prismatische Ziegel durch Anwendung von herkömmlichem Ton und Beimischung von jeweils 1, 3 und 5 Masse-% Lederabfall hergestellt. Die Prüflinge wurden in Bezug auf Durchbiegung, Verdichtung und Auslaugung untersucht. Die Ergebnisse haben gezeigt, dass die Ziegelmassen keinerlei Toxizität aufwiesen, wobei die Prüflinge mit Abfallzusatz eine verringerte Festigkeit hatten. Jedoch waren diese Ziegel leichter und mit mehr Poren versehen, sodass man daraus schließen konnte, dass die Ziegel in der Anwendung eine bessere Wärmeisolierung gewährleisten würden.

Valorisation de résidus de cuir par l'incorporation en briques

L'industrie des chaussures a beaucoup de bandes de cuir comme un de ses sous-produits. Ces résidus de cuir, à cause des quantités élevées de chrome, peuvent être dangereux pour l'environment, surtout si on ne fait pas attention à sa disposition. Avec l'incorporation des résidus en produits céramiques, il est possible de neutraliser la toxicité du chrome. Dans une étude laboratoire nous avons fabriqué briques prismatiques avec l'argile de la région et l'incorporation de 1, 3 et 5 % (en masse) de résidus de cuire. Ces incorporations correspondrent à 20, 60 et 100 % (en volume apparent). Les briques ont été soumises aux essais de flexion, compression et lixiviation. Les résultats ont montré que la toxicité du chrome n'est plus présente. Les essais mécaniques ont montré une décroissance des résistances des éprouvettes avec résidus. Cependant, comme les briques demeurent plus légères et plus poreux, nous pouvons attendre qu'ils ont mieux isolation thermique.

Valorización de residuos de cuero a través de su incorporación en ladrillos

La industria del calzado produce tiras de cuero como uno de sus residuos. Este cuero, debido a su alto contenido de cromo, puede considerarse como un peligro ambiental, particularmente si no se tiene cuidado con su manejo y destino final. Con la incorporación de estos residuos en productos de cerámica, es posible neutralizar la toxicidad del cromo. En un estudio de laboratorio, se produjeron ladrillos prismáticos usando arcillas de la región e incorporando 1, 3 y 5 % en masa de residuos de cuero. Esto corresponde aproximadamente con 20, 60 y 100 % en volumen aparente, respectivamente. Los ladrillos fueron ensayados en flexión, compresión y lixiviación. Los resultados muestran que la toxicidad del cromo desaparece en los ladrillos. Las pruebas mecánicas evidencian una menor resistencia de las piezas con residuos de cuero. Sin embargo, debido a que los ladrillos fueron más ligeros y porosos, puede esperarse que tengan mejores propiedades de aislamiento térmico.