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An accelerated test to assess the quality of recycled concrete sands based on their absorption capacity

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HIGHLIGHTS

- The standard test to determine the absorption of sands is long and laborious.
- A fast method to test the water absorption of recycled sands has been developed.
- The new test uses an electronic moisture analyzer based on thermogravimetry.
- The new test is fast and simple, being an automatic process with no operator need.
- The absorption results have been satisfactory compared to the standard method ones.

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ABSTRACT

The standard test to determine the absorption of sands according to UNE-EN 1097-6 is long and laborious to carry out, even more when it is applied to recycled sands due to its typical high absorption.

The aim of this study has been to develop a fast and reliable method to test the absorption of recycled sands. For that purpose, the absorption of fourteen recycled concrete sands has been determined using an electronic moisture analyzer based on thermogravimetry. This analyzer provides thermogravimetric curves (weight–time curves) from which drying rate–humidity and drying acceleration–humidity curves can be plotted. The results have been satisfactory compared to those by the standard method for all the recycled sands. The new test is fast (around half an hour) and simple, being an automatic process with no operator need and providing a numerical result.

This method can also be used for accelerated tests of recycled sands after an immersion period of 10 min. In the experimental programme, it has been established a correlation between absorption after 10 min and 24 h immersion in water for the recycled sands.

1. Introduction

Recycled sands are heterogeneous materials due to its diverse origin, so it would be important for recycling plants to have at their disposal rapid methods to detect and reject low quality lots along the production process.

According to standard UNE-EN 1097-6 [1], absorption is defined as the water content of an aggregate in saturated but surface dry condition. The standard test for absorption of sands is that obtained after immersion of the sample 24 h in water.

Absorption is a quality index for recycled sands, as it is related to other important properties (density, fines content, freezing and thawing behaviour, etc.). Moreover, absorption of recycled sands usually reaches higher values than natural sands, leading to a detrimental influence on the consistency of concrete and mortar. Therefore, international standards include requirements for absorption of sands. Table 1 shows limits applied to the maximum absorption of recycled sands in different international standards [2–6].

The European standard test for determination of absorption of sands (standard UNE-EN 1097-6) consists of immersion of the sample in water for 24 h with a subsequent drying under a current of warm air to evaporate surface moisture. Throughout the process of drying, the humidity of the sample (water content) is visually checked filling a normalized metal mould shaped like a frustum of a cone. If superficial water is still present, the sand cone will

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not collapse at mould removal. When the collapse situation occurs and the slopes of the collapsed sand cone are angular with definite peak still visible it means that the sample has achieved the saturated surface dry state, being the humidity at that point the absorption value.

However, the cone test is long and laborious to carry out, even more when applied to recycled sands because of its high absorption, which makes necessary a long drying period. Moreover, saturated surface dry condition is determined by a subjective visual inspection and the shape of the collapsed sand cone is also influenced by the characteristics of the material (nature, grain size distribution, fines content, particle shape, surface roughness, etc.). Therefore, it would be very useful to find an alternative test method to obtain a reliable value of absorption in a short period of time. This test could be applied, for example, in recycling plants to check periodically the production in order to detect and reject low quality lots.

There are some alternative methods proposed in literature for absorption of recycled aggregates:

- Measuring and recording continuously the weight of a wet sample kept inside a climate chamber, where drying conditions can be controlled. A temperature of 65 °C is used for drying and ventilation supports the removal of the evaporated water. When the observed drying rate falls below 0.02 g/min the temperature is increased to 105 °C. After complete drying has been achieved the drying rate is plotted against the moisture concentration of the tested material. Regression analysis allows an automated identification of the transition from constant drying regime to decreasing drying regime, which is taken as the indication that the material has reached a surface dry condition. A narrow band width of the sample allows a clear interpretation of the recorded drying curve. This method is fully automated, so no continuous attendance by personnel is required, and the results for coarse aggregates are in good agreement with those obtained by the standardized method. However, recycled sands and materials with a high concentration of fines caused some uncertainty in detection of the transition point, so if this is the case bigger size samples should be used. Furthermore, the method is still long to carry out, as a test run is completed within 24 h and preconditioning of the test materials consists of ponding in water for 24 h [7,8].
- Saturating the aggregates in vacuum conditions in order to reduce absorption time up to 30 min. Afterwards, the aggregates are dried in a microwave oven, monitoring the weight of the sample until the dry conditions are reached (around 2.5 h). The whole test is completed within 4 h and the absorption point is obtained from the drying rate curves, being also unclear its exact determination. However, the test is only proposed for coarse aggregates and it gives higher absorption values than the standard method (increase of samples pores saturation because of vacuum conditions). This work also studied alternative methods for drying (oven and infra-red radiation), but longer drying periods were required and the results presented high experimental scatter [9].
- Finally, the german standard DIN 4226-100 describes a method to obtain "an indication" of the short-term absorption of recycled sands. The sample, previously dried to constant mass and cooled to ambient temperature in a desiccator, is then placed in a shallow tray and sprayed with water while stirring, until the surface of all particles is lightly wetted. At that moment, the wet sample is weighed to determine the absorption value. This procedure is very subjective, as the amount of water to be sprayed is at the discretion of the operator. Due to the high capacity of the sand to retain superficial free water the results are subject to important scatter.

As described above, none of these methods has solved definitely the characterization of the absorption of recycled sands in a short period of time.

2. Background: theoretical basis of the drying behaviour of porous materials

Drying kinetic of granular porous materials has been extensively studied because of its importance in very different fields (food dehydration, chemical dryers, ceramics, etc.). For all these materials there is an agreement in the characteristic drying rate vs. humidity curve that is obtained, which is shown in Fig. 1. In this typical drying curve under constant temperature, the following drying stages and mechanisms have been described [10–14]:

(1) Phase A–B: Stage at increasing drying rate. Initial period of heating until the regime temperature is reached.
(2) Phase B–C: Stage with a constant drying rate. In this period there is a continuous free water film over the material grains and evaporation of this superficial water takes place, but capillary forces are strong enough to replace the evaporating water. This stage finishes when the Critical Humidity is reached (point C), defined as the water content when the water film over the particles is no longer continuous. At this critical point, the radius of curvature of the meniscus is small enough to enter the pores.
(3) Phase C–D: First stage at decreasing drying rate. In this period, further evaporation drives the meniscus into the pores. The liquid in the pores remains in the funicular condition (moves along the pore walls), so there are contiguous pathways along which flow to the surface. Most of the evaporation is still occurring at the exterior surface, but, at the same time, some liquid evaporates within the unsaturated pores and the vapor is transported by diffusion. As the meniscus recedes into the pores, the exterior does not become completely dry right away, because liquid continues to flow to

Table 1
Water absorption limits for recycled sands.

Standard	Absorption (%)	Application
DIN 4226-100	⩽10	Mortar and concrete
NBR 15116	⩽12	Structural and non-structural concrete
JIS A 5021	⩽3.5	Structural concrete
JIS A 5023	⩽7	Concrete
JIS A 5022	⩽13	Concrete not suffering from drying shrinkage or freeze–thaw cycles

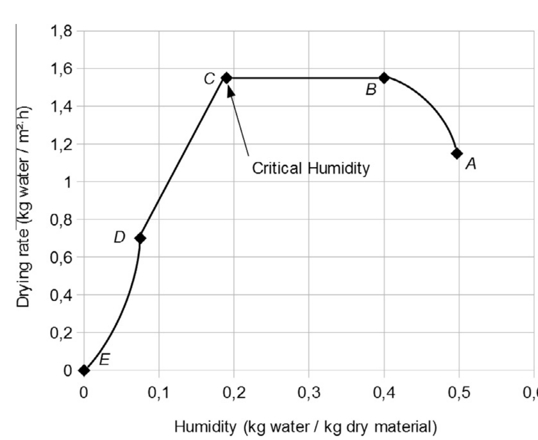

Fig. 1. Drying curve of porous materials under constant conditions.