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DVS Application Note 61

Characterizing the Restoration Materials for Historic Buildings Using Dynamic Vapour Sorption Technique

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It is important to choose the right building materials for restoration of buildings and heritage structures. Old and new materials with near identical properties, especially relating to moisture ingress and water holding capacity are desirable to avoid ominous deterioration. DVS studies on various materials have been conducted to obtain their hygroscopic behaviour which are indicative of their suitability at site..

Introduction

The moisture sorption properties are regarded as important characteristics of materials. In particular, these properties become critical factors to building materials such as bricks, stones, cement, mortar, timber and fibre. Moisture damage brought upon building materials is significant in affecting and limiting the life of the building. In this context, investigating the moisture ingress properties of used building materials in a heritage structure is particularly important for the restoration materials needed to carry out repairs and remedial measures. Compatibility of old and new materials is desired. In addition, moisture infusion through a building's outer structure can have a significant effect on thermal behaviour of materials, indoor air quality and air conditioning load. When compatible materials with near identical moisture holding capacity and thermal expansion properties are used it is likely that the combination will act well against hydration and humidification.[1,2,3,4]

DVS studies have been performed on building materials from Abbey Mill - an 18th century, grade II listed building (Tewkesbury, UK) . The samples were processed on a DVS automated moisture sorption instrument at 25^{o}C for obtaining change in mass and isotherm plots.

Method

All the samples were analysed on a DVS, automated moisture sorption instrument at 25^{o}C, with a sample size of 22 - 65mg for each analysis. The samples were initially dried for 300 minutes under a continuous flow of air to establish the dry mass. The samples were then exposed to the following typical partial pressure profile: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 90, 80, 70, 60, 50, 40, 30, 20, 10, and 0% relative humidity (RH).

For all the RH steps, the instrument was run in a dm/dt mode (mass variation over time variation). A fixed dm/dt value of 0.002 % min^{-1} was selected. This criterion permits the DVS software to automatically determine when equilibrium has been reached and complete a relative humidity step. When the rate of change of mass falls below this threshold over a determined period of time, the humidity will proceed to the next

programmed level. A maximum stage time of 360 minutes and a minimum stage time of 10 minutes were selected for all experiments.

Results

Typical net percent change in mass (based on dry mass) versus time plots at 25°C for Abbey Mill old brick, Millbarh stone, Abbey Mill new brick, Abbey Mill Mortar, Millbarh Mortar, Millbarh Timber, and Odda chapel samples are shown in Figures 1a-7a, respectively. The red line plotted on the left y-axis, indicates the percentage change in mass referenced to the dry mass (after initial drying stage), m0, as a function of time. The blue line, plotted on the right y-axis, traces the requested % partial pressure of water vapour in the DVS as a function of time.

The kinetic plots for samples, depicted in figures 1a-7a and the comparison plot in figure 8a, show relatively high uptakes, indicating bulk absorption or the presence of pores. However there are differences in water sorption capacities and general water sorption mechanisms. The rank order for increasing uptake is as follows:

Abbey Mill Old brick, 1.2% ; Millibarh stone, 1.5% ; Abbey Mill Newbrick, 1.6%; Abbey Mill Mortar, 3.5% ; Millibarh Motar, 11.69%, ; Millbarh Timber, 22.93% ; Odda Chappel 24.73%

Water absorption properties are useful indicators of durability. High water absorption leads to excessive moisture in the building materials and in turn promotes biological growth processes like fungi, algae and bacteria, all detrimental to durability. There is also a reduction in thermal insulation rendered by these materials with rise in moisture content, as thermal conductivity of damp materials are much higher.

Therefore, it is important to choose materials exhibiting low water absorption capacity and high strength. In the findings of this current study, the materials with high water uptake like Abbey Mill Mortar, Millibarh Mortar, Millibarh timber and Odda chappel do not appear to be very good building materials because of the cited reasons.

In contrast, the percentage of water uptake for Abbey Mill New brick, Abbey Mill old brick, and Millbarh stone are low and similar to each other. Because of their identical uptake properties they may be considered compatible and can replace one another during refurbishing and repairs. Lower uptake properties also indicate durability of these materials.

The sorption isotherm comparison plot is displayed in Figure 9a.

The isotherm plots display the percent change in mass (referenced from the dry mass, m0) versus the requested relative humidity.

These plots confirms that the Abbey Mill old brick, Abbey Mill new brick and Millbarh stone display lower water sorption capacity in comparison to other materials (Figure 9a). This finding is beneficial from the practical point of view, since the usage of hygroscopic materials in some building structures can cause problems, with respect to their functionality and durability.

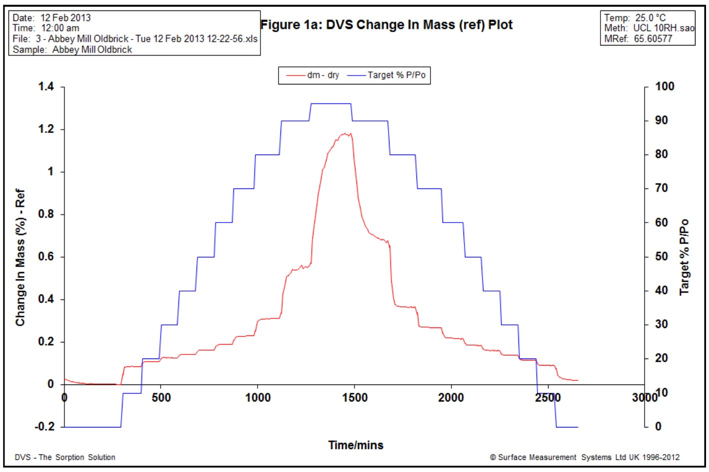


Figure 1a. Water vapour sorption kinetics for Abbey Mill Oldbrick sample at 25°C.

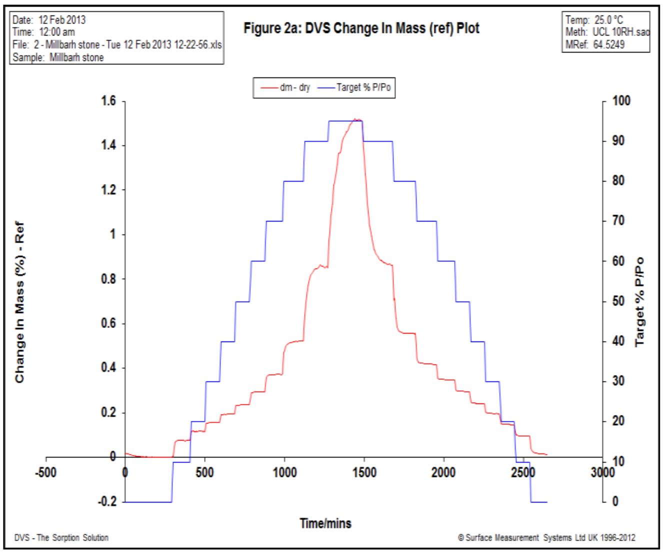
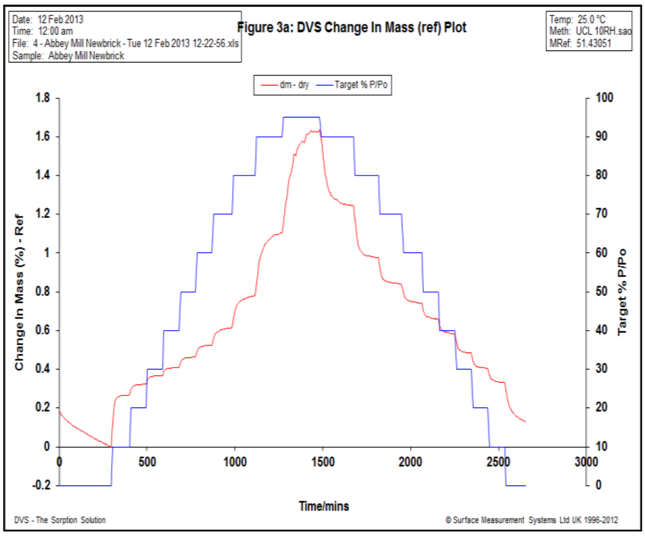


Figure 2a. Water vapour sorption kinetics for Millbarh stone sample at 25^{o}C



3a. Water vapour sorption kinetics for Abbey Mill Newbrick sample at 25oC

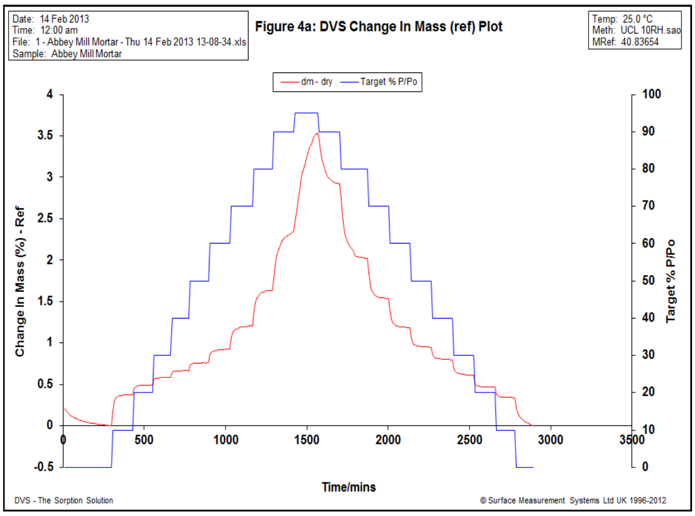


Figure 4a. Water vapour sorption kinetics for Abbey Mill Mortar sample at 25^{o}C.

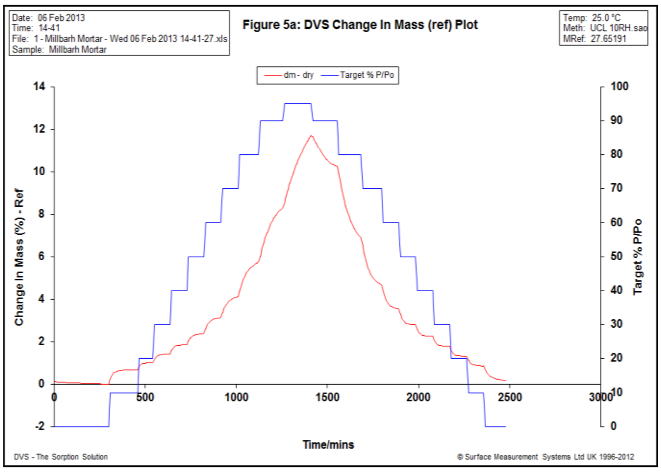


Figure 5a. Water vapour sorption kinetics for Millbarh Motar sample at 25oC.

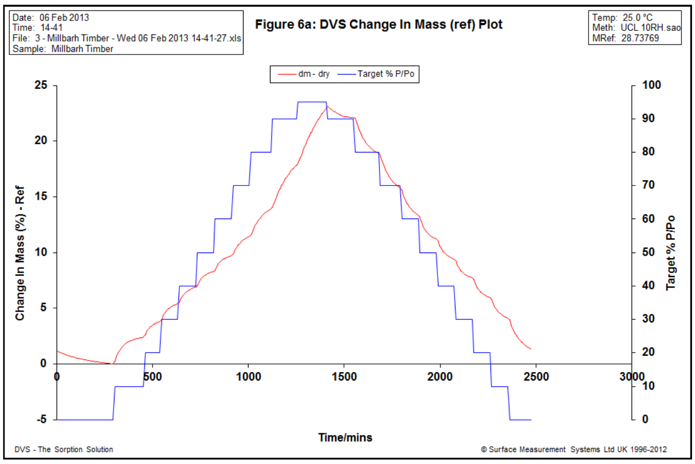


Figure 6a. Water vapour sorption kinetics for Millbarh Timber sample at 25^{o}C.

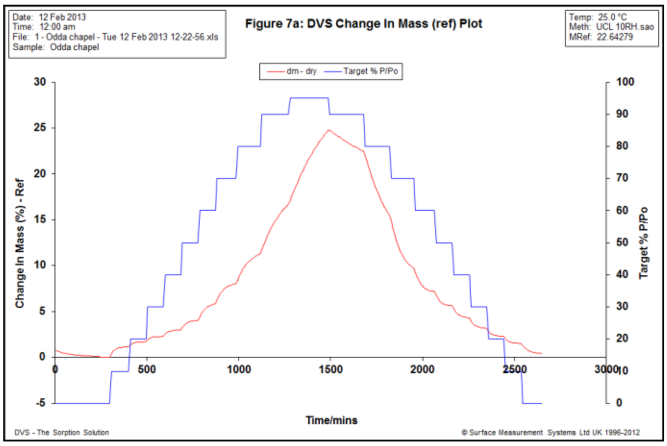


Figure 7a. Water vapour sorption kinetics for Odda Chappel sample at 25^{o}C.

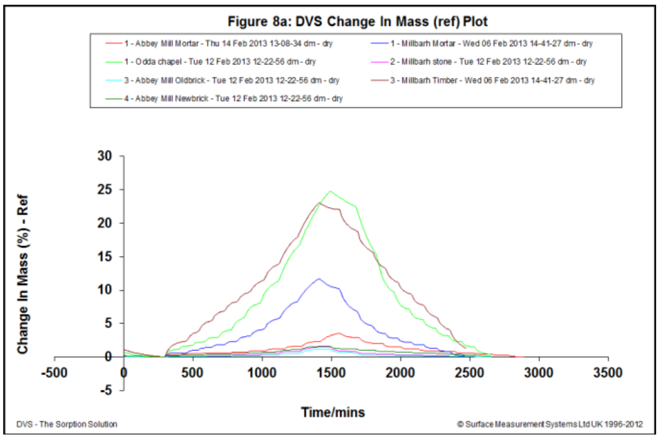


Figure 8a. Comparison water vapour sorption kinetics plots for all samples at 25^{o}C.

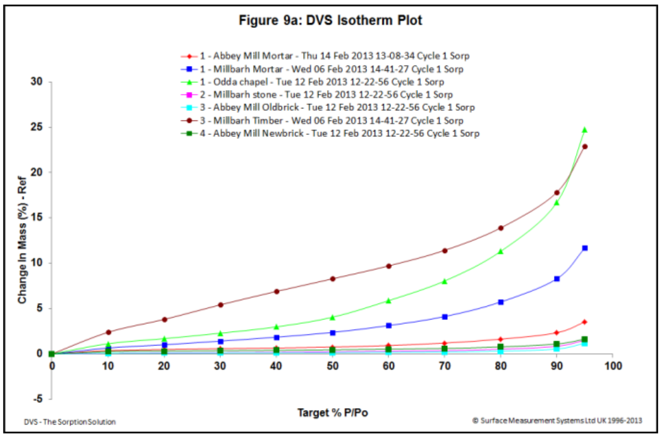


Figure 9a. Comparison Water vapour sorption isotherms for the samples at 25^{o}C.

Conclusion

The adverse effects of moisture in building materials and structures are well documented. It is therefore imperative to prevent moisture ingress into the buildings for their whole service life to avoid deterioration. In case of damp brick masonry, there are several methods that can be applied for its reconstruction, restoration or renovation. In this note, the experimental investigation is presented in order to assess the correct building material and its applicability in the rehabilitation of buildings. In the findings of current study, the materials with high water uptake like Abbey Mill Mortar, Millibarh Mortar, Millibarh timber and Odda chappel do not appear to be very good replacement building materials. In contrast, the percentage of water uptake for Abbey Mill New brick, Abbey Mill old brick, and Millbarh stone are low and similar to each other and may be considered compatible and can replace one another during refurbishing and repairs.

Acknowledgement:

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