



## Mounting of sensors on surfaces in historic buildings



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### ARTICLE INFO

#### Article history:

Available online 26 November 2014

#### Keywords:

Measurements  
Surface temperature  
Heat flow  
Sensors  
Reversibility  
Mounting  
Volatile binding media

### ABSTRACT

Museums are often housed in historic buildings or sometimes also the building itself is part of the exhibition, like open-air museums. In heritage buildings, it can be necessary to monitor the hygrothermal behavior of building components and the indoor climate for conservation purposes or for energetic refurbishment. When measuring heat flow and surface temperature, direct contact between sensor and surface must be ensured reliably over the entire measurement period. These installations are usually performed by technicians and not by conservators. Conventional installation procedures cannot be carried out without damages to sensitive original surfaces when the sensors are removed later.

The aim of this cooperation between building physicists and conservators is to develop a system, where neither substance losses occur nor unwanted residues with unknown aging behavior remain after dismantling the installation and which does not affect the measurement results significantly.

For this purpose new mounting systems for surface sensors and other technical installations have been developed, tested and applied. Test measurements were carried out to assess uncertainties of the different reversible mounting systems in comparison to conventional methods.

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### 1. Introduction

For the preservation of built heritage and most works of art, the climatic conditions are an essential factor. For gaining knowledge about damaging processes, on the state of preservation of buildings and artefacts, as well as for building physics issues, it is sometimes important to carry out detailed and permanent microclimate measurements for longer periods. In valuable historic buildings or for important artefacts, conservation issues prevail. On the other hand, only non-destructive methods or methods with the least damages to the original materials can be taken into account for any kind of analytics or measurements in these buildings.

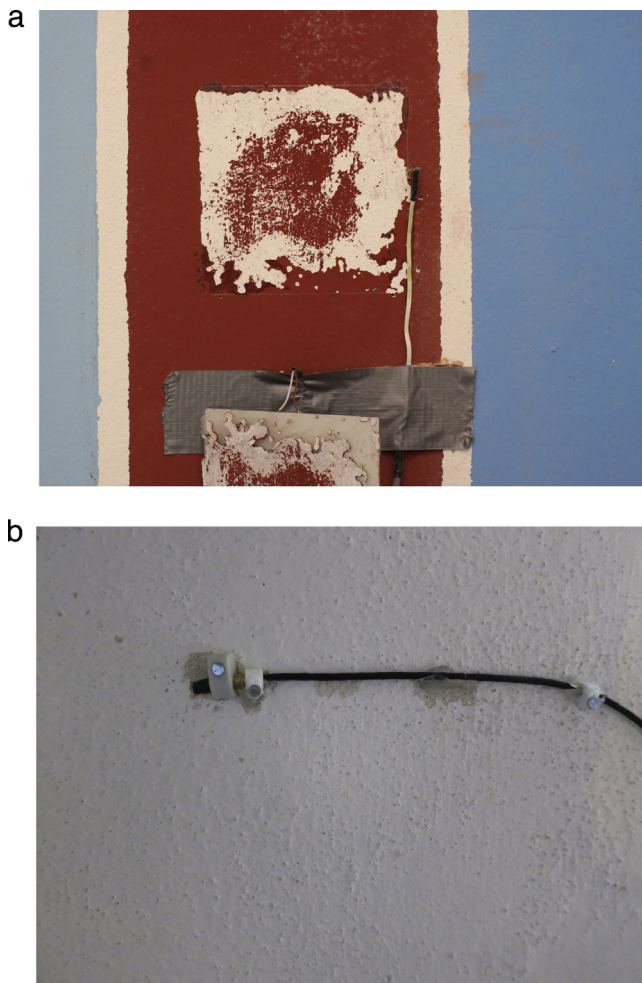
The conventional mounting procedures carried out by measurement technicians unavoidably lead to damages to sometimes valuable historic surfaces and often leave residues of materials with unknown aging behavior. These had to be accepted up to now. In that way, measurements in historic buildings are critical and therefore only restrictively allowed by the heritage administration or staff in charge. Sometimes, more or less damage free methods which are not tested in detail were applied.

In recent literature, the topic indoor climate is mostly split up between the field of conservation, where conservation techniques and material degradation are tested and discussed, and the field of building physics. Sensor mounting systems adequate from a conservator's and a building physicist's point of view has apparently never been assessed in detail. For example, measurement procedures and measurements accuracy in historic buildings are thoroughly explained but no details about mounting of surface sensors are given [1,2].

Commonly used mounting systems are adhesive systems like glues and bonds. The sensors can be bonded directly to the surface. Alternatively or in combination tapes are in use. Also thermal conductivity paste in combination with tapes, bonds or nails are applied sometimes. Another possibility is to fix the sensor with screws or nails in fixtures or holders, which in some cases are additionally combined with glues, tapes or thermal conductivity paste. These materials and methods are still in use and standard procedures for normal laboratory or field measurements in test buildings or buildings without any special requirements are used. First tests on reversible mounting systems were made at the outdoor test facility at Fraunhofer IBP Holzkirchen in a test house with a special paint layer composed according to a historic recipe. Fig. 1 shows on the left picture a removed conventional bonded heat flow meter with the damage that occurred to the surface.

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**Fig. 1.** (a) Heat flow meter with surface temperature sensor during removal. The heat flow meter was bonded to the surface conventionally with epoxy resin and in use for six months during the cold period. The paint layers are destroyed, residues of the epoxy resin remain on the surface. (b) A surface sensor in a historic building of an open air museum with losses of white-wash (Source: Fraunhofer IBP).

For several years a further developed technique with hot-melt adhesive is in use for sensible surfaces. Hot-melt adhesive is – provided that it is used with care – a clean looking, simple and durable way for mounting sensors. The thermal stress for the surface is highly local during the short time span of curing. One problem is that the ingredients of these thermoplastic resins are unproved and a potential plasticiser migration into the historic surface may occur. In many cases, the problem occurs that the hot-melt adhesive will connect well to the surface, but the surface itself is powdery – a failure inside the surface along with irreversible losses and unwanted coming off of the sensor is the result. Removing the hot-melt adhesive after the measuring period is potentially risky and not easy to handle. In most cases, residues of the hot-melt adhesive have to remain on the surface, losses and damages of the surface layers occur. Due to these facts, several organisations do not allow any further measurements on surfaces with this method. In Fig. 1b a surface temperature sensor is shown. The surface and the plaster underneath are very weak and sandy. This has led to a poor bonding of the hot-melt adhesive and made an additional fixture with nails necessary. The result is a good heat transfer contact to the surface but combined with losses of the surface paint and partly of the plaster.

In the current research project “Temperierung Heating as a Tool for Preventive Conservation in Museums”, measurements in

different museums housed in historical buildings are carried out. For this purpose, new methods, which do not cause harm to the surfaces and do not affect the quality of the measurements, are required. In EN 15758 [3] it is stated out that measurement on surfaces are potentially risky to surfaces and should only be done after consultation of a conservator.

According to conservation ethics there is no real “reversibility” of any kind of treatment of a historical surface possible. A material has to be chosen, which is as little harmful as possible for the surface where it is applied on [4,7]. Residues, which remain in any case, have to be as non-aging as possible. These materials can vary from case to case [7]. A selection for different approaches is given hereafter.

## 2. Mounting types and materials for mounting sensors on historical surfaces

There are three questions to be answered for each particular measurement task:

1. How long is the duration of the measurements?
2. What are the quality and specific properties of the surface?
3. How sensitive and valuable is that surface?

The duration of the measuring is decisive for the selection of the method for mounting sensors onto surfaces. For a three to six months' time span, using methods with volatile binders is possible. Volatile binders, like Cyclododecane, are binders that will dissolve (or sublimate) under normal ambient air conditions from a wax like, solid state into a gaseous state during a certain period of time.

For longer periods of measuring, the historical surface is lined with Japanese tissue paper and a binder. This treatment of the surface is commonly known to conservators. The choice of the binder and its solvents is dependent on the use – outdoors or indoors – and fundamentally on the properties of the surface. The used binder should be non-aging and resoluble in solvents (in which the original surface is not solving).

There are no standard procedures that can be applied for historic works of art and their surface, because every coating reacts in a different way when treated with solvents. Additionally, many aged paint layers have a brittle or powdery surface. In historic buildings, the surfaces have a different aesthetic and historic value. Due to this fact, for detailed measuring it is reasonable to take into account surfaces with less prominent positions.

Last but not least, one has to think ahead about the possibilities for demounting the sensor, i.e. adequate solvents and methods for both, the mounting and the historic surface [7].

Based on this experience the existing mounting systems were further developed. Aim of the development was to get optimized sensor mounting systems which can be easily applied, does not bias the measurement and can be removed without damaging the original surface. In Table 1 the tested materials and sensor mounting methods are listed.

### 2.1. Materials taken into account as adhesives for sensors on historic surfaces

Cellulose ethers are common materials for a broad range of conservation treatments. In humid environments, some types are preferably attacked by microorganisms. Choosing types which are known to be less susceptible to microbiological attack is favorable. Some types are soluble in water and polar organic solvents, thermoplastic and surface-active [7]. Solutions in ethanol or acetone enable the consolidation of glue paint layers without water stains.

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