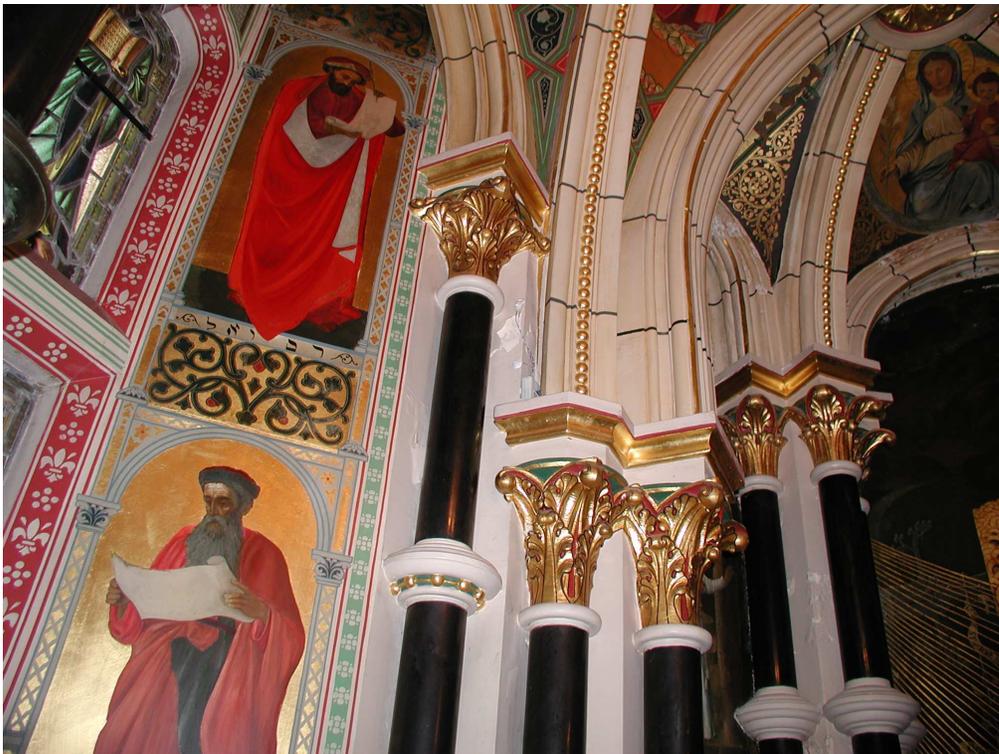


# Chapter 12

## **Environmental monitoring: inspection, investigative monitoring techniques for historic buildings and case studies - brief paper**

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### **1 Summary**



**Photograph 1** Decorative finishes in Cardiff Castle

Environmental monitoring is the key for environmental risk assessment of historic buildings their structure, environments and contents. Environmental monitoring can include a range of parameters that can be monitored, but the most important in historic buildings are, for example, weather stations, Internal,

external, fabric and material monitoring, moisture profiling and mapping. Measured parameters include UV, Lux levels, temperature, humidity, dew point, and vapour pressure.

Data from both short term and long term monitoring is analysed and can be used where necessary to recommend a range of measures, which can be implemented to achieve optimum environmental conditions. This could include installation of a permanent monitoring system by an independent company, if necessary to link up with the BMS system, which could alter the environment within the building. This is particularly applicable in historic buildings, Museum and Galleries, Castles, Libraries and Archives.

The presentation includes case studies on Cardiff Castle, Cardiff, Wales, Farmleigh House, Dublin, Ireland and Guys Hospital, London.

## 2 Keywords

**Environmental Monitoring, Inspection, Investigative Monitoring Techniques, Historic Buildings and Case Studies**

## 3 Introduction

Damage to the fabric of historic buildings caused by environmental factors is a complex problem. In order to assess the environmental impact on a historic building monitoring will need to be carried out. There are many techniques available for assessing this each of which has its merit depending on the situation.

There are many parameters that have to be taken into account when considering such a task.

What is the purpose of the monitoring exercise? The more specific the brief the better will be the results. An unspecific monitoring brief will not provide good results.

Once the specific problem has been identified a preliminary inspection of the building should be carried out. This will enable building defects to be identified and potential problems in locating of logging equipment.

As much as Information about the building should be gathered, from historic documents and plans to conversations with the owners and or curators of the building. For instance if the masonry is to be monitored the wall construction should be determined if possible. Possible destructive investigation may be necessary to determent this, if accurate and meaningful results are to be obtained.

**Photograph 2** Showing UV/Lux data logger for the measurement of measurement UV and Lux levels.



**Photograph 3** Showing surface reading of environmental conditions



## 4 Monitoring Equipment

### 4.1 Hand Held Monitoring Equipment.

Hand held non-destructive monitoring instrumentation would generally be used to identify local defects and general building problems. Once identified, more detailed monitoring can be carried out if necessary.

These instruments most commonly include timber and masonry moisture content meters, temperature, relative humidity and condensation meters. More specialist measuring equipment can also be employed such as 'Resistograph' (decay detection drill) and Infra red thermography, for detection of hidden timbers and moisture in structures.

#### 4.1.1 Moisture Meters

Generally these are resistance or capacitance meters, which measure the changes in electrical resistance between two electrodes with changes in moisture content of the material. They are relatively accurate when measuring moisture in timber up to 27% moisture content but can be affected by chemical treatments to the timber, types of surface finishes and ancient timbers which have the effect of giving false high readings.

**Photograph 4** Monitoring RH in wall void



They can also be used to measure moisture contents of masonry but great care should be taken in interpretation of results as they are adversely affected by, certain paint finishes, salts and condensation. They are most useful in giving a measure of surface dryness. If high readings are identified then further investigation will be necessary possibly using mortar sampling if circumstance allow.

#### 4.1.2 Relative Humidity and Temperature Meters

The level of Humidity in a building can be a good indicator of potential building defects. This coupled to temperature measurement can enable condensation risk to be assessed.

For the measurement of relative humidity in concrete and masonry, sealed plugs are inserted to 40% of the depth of the masonry to be measured. After a minimum period of 10 hours the seal is broken and the relative humidity noted after a period of equilibrium has been reached.

This method is generally used where the material is too hard to test by the gravimetric sample method described below.

Readings of 75% Relative Humidity or less indicate that the material is dry (BS 8203 and BRE Digest 163).

**Photograph 5** Environmental monitoring at Cardiff Castle



### 4.1.3 Data loggers

There are now available a number of 'matchbox' sized data loggers on the market. These are small enough to be positioned inconspicuously within buildings and are accurate and user friendly.

They generally measure temperature, Relative humidity, dew point, vapour pressure, Lux, Ultra violet and Timber Moisture Content.

They have the disadvantage of having to be downloaded locally but this can be used as an opportunity to carry out a visual inspection of the building, when they are downloaded. They are sufficiently small to be posted back and forth, if necessary.

The loggers can be programmed to log data from a few seconds to daily and can if necessary store up to a years data.

Additional external measurement probes can also be added so that for instance surface temperature and humidity can be measured if necessary.

**Photograph 6** Environmental monitoring at Cardiff Castle



#### 4.1.4 Radio Telemetry Systems

Data loggers that are linked via a radio telemetry system allow numerous loggers to be positioned in a building with minimal wiring (and the problems of running such systems). They are also downloadable over the Internet and enable remote monitoring making monitoring of less accessible buildings easier and more cost effective. However the additional cost of such systems should be considered against the cheaper non-telemetric systems and the disadvantages described above.

Generally these systems are used as permanent installations rather than for monitoring over a short period.

### 4.2 Physical Testing

#### 4.2.1 Masonry Mortar Sampling

These tests are carried out by taking a sample(s) of mortar or masonry by drilling a hole and collecting the mortar in a sealable container or bag. The sample(s) are weighed and then dried for a period until no further weight loss is detected. The sample is re-weighed and the percentage moisture content is calculated (BRE Digest 245). The level of hygroscopic salts can also be determined by placing the dried sample in a 75% RH for 12 hours then reweighing. With the total moisture content and hygroscopic moisture content known the free moisture content (moisture due to water penetration) can be calculated.

**Photograph 7** Environmental monitoring with wall probes at Cardiff Castle



This enables us to distinguish between current and historic problems.

If the material to be tested is too hard then the Relative Humidity method as described above should be used.

#### **4.2.2 Resistograph Inspection & Analysis**

Deterioration of structural timber elements is investigated with the use of non-destructive 'Resistograph' instrumentation.

## **5 Monitoring Plan**

### **5.1 Case Studies**

#### **5.1.1 Cardiff castle, Cardiff**

##### **1 Background**

The brief from the client in this case was comprehensive. The client knew which parameters were to be monitored and the overall scope of the works. The scale of the monitoring exercise was large in comparison with most projects.

The castle dates back 2000 years but many changes and additions have taken place since this time. The most significant of these was during the nineteenth century were the second Marquess of Bute in collaboration with William Burgess created fifteen neo-gothic medieval highly elaborately decorated rooms.

These decorations were applied directly to the wall surfaces, some of which were now showing signs of water and salt damage.

The monitoring exercise was to determine what was the cause of the failure and to put into place remedial measures to reverse these changes.

##### **2 Monitoring**

The monitoring exercise was carried out in conjunction with other consultants; Paint and surfaces consultants, stone and mortar consultants and services engineers.

The following parameters were monitored:

- Internal RH,
- temperature,
- Lux, and UV,
- Dew point and Vapour pressure

- Wall surface RH, temperature, Dew point and Vapour pressure and
- The temperature, RH, vapour pressure and Dew point within the masonry at varying depths.

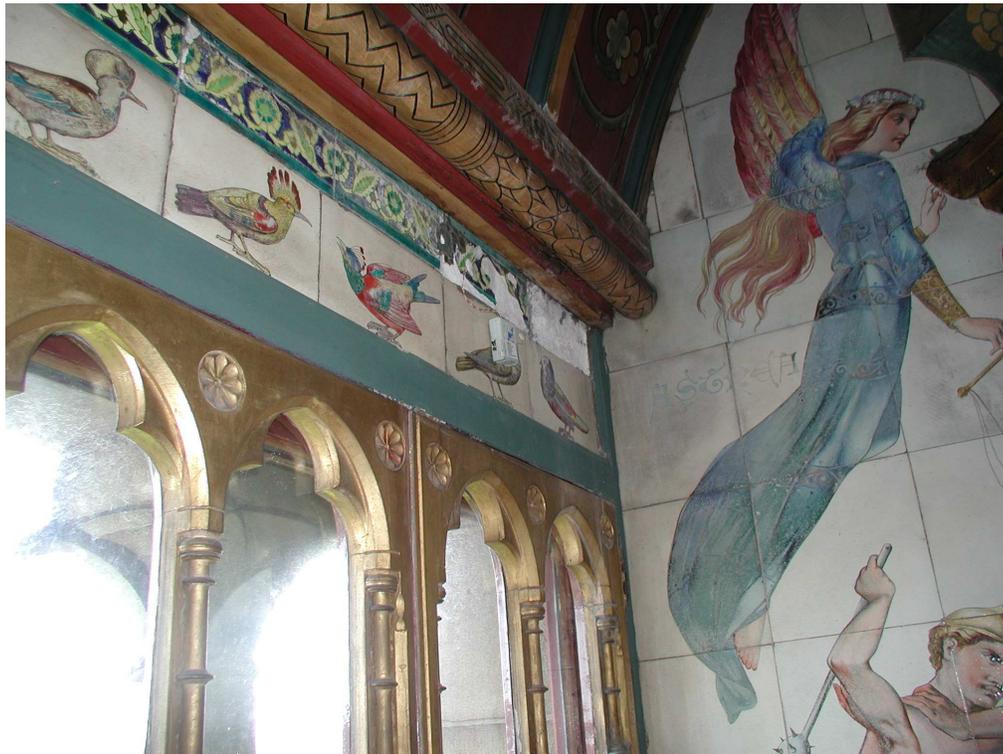
On the exteriors of the building the

- RH,
- temperature,
- wind speed and direction,
- rainfall and solar radiation were monitored.

A total of 60 loggers were used which presented a number of problems in both data gathering and analysis.

If this number of loggers is to be used then ensure that the type of logger employed has a simple and efficient method of downloading the data. Ideally it should be possible to download the loggers in situ.

**Photograph 8** Cardiff Castle showing deterioration to decorative finishes



A telemetric system would be ideal for this purpose particularly if fitted with a modem for remote download. However in this case this was not considered necessary as site visits to regularly inspect the building for signs of deterioration could be carried out at the time of downloading.

Attachment of loggers to ornate surfaces should be considered carefully. As does the location of loggers away from the clutches of the general public. A compromise has to be made between this and the ideal location of the logger from a data-gathering viewpoint.

The vast amount of data collected each month presented a problem mainly because of the time consuming process of inspecting the graphs for relevant results. The different types of loggers and there dedicated software made data manipulation difficult as they were not compatible and further processing was needed to make direct comparisons.

## **5.1.2 Farmleigh House, Dublin**

### **1 Background**

Farmleigh house is situated in the middle of Phoenix Park, Dublin.

Major works were carried out to Farmleigh house during 2000-2001 after the Irish government bought the building in 1999. These were the most significant undertaken since the 1880s when the house was remodelled by Edward Cecil Guinness.

The house needed extensive renovation and the opportunity was taken to update and improve the existing house and services including improved access.

Minimal intervention was used at ground floor level to minimise damage to timber wall panelling which is a feature of many rooms at this level.

Most of the rooms including the bedrooms are finished to a high standard and include sculptures, textiles and paintings.

Following the refurbishment it was decided that the environment in the building should be monitored to ensure that the environment was not detrimental to the building fabric, contents and occupants.

### **2 Monitoring**

Data loggers were placed throughout the building with an external logger and rain gauge. A total of 21 loggers were used, measuring air temperature and relative humidity.

These were placed in locations that were accessible but hidden from view to the guests and visitors to the building.

A Lux and Ultra Violet logger was also used in the Library to measure the potential effect on the books stored therein. Many of which, are of major historic importance.

The loggers were set to log every 15 minutes for two-month periods. They were downloaded locally and reports prepared.

### **3 General Conclusions and Results**

The environmental conditions within the building were generally found to be acceptable during the summer months, however during the autumn and winter conditions deteriorated.

This was due to a combination of external influence on the internal conditions and internal heating. The external relative humidity was found to be the major influence on the RH within the building throughout the year.

During the autumn large fluctuations in external humidity and temperature influenced the internal environment, which in combination with intermittent internal heating created large fluctuations in the internal environment.

During the winter in particular the external relative humidity was often low this reduced the internal RH which in combination with heating reduced the RH still further giving RH as low as 20% in some rooms for short periods and longer periods of RH between 30 and 40%. This is likely to cause damage to timber panelling, furniture and paintings.

There was however little evidence of damage to the internal fabric, for instance cracking and damage to the timber panelling.

Two of the bedrooms did have an air conditioning system, which was able to control the internal environment at acceptable levels but external influence was also noted in these rooms.

Ideally the Relative humidity in all rooms in the building should be maintained at between 50% and 65%, which is sufficiently high to prevent shrinkage of furniture and panelling but not too high as to encourage mould growth and condensation.

A compromise between the comfort levels of the occupants of the building and acceptable temperature levels to control the RH to prevent damage to the fixtures and fittings has to be made.

This will be difficult to achieve with the current heating management system.

A heating Engineer should be consulted regarding the best way of achieving the conditions of RH described in 5.1 above. He should be provided with the reports prepared by EBS for information.

## **4 Recommendations**

The following should be considered;

Consideration should be given to installation of a new heating system, which is fully automatic and can respond to external weather changes quickly.

Investigate whether the existing system can be upgraded to provide a fully automated system responding to external conditions.

Investigate whether the existing system can be upgraded to provide better control than currently provided with some response to external conditions.

Whichever system is used it will not be possible to provide ideal conditions, such as that provided for museums and libraries as this is not a sealed modern building but a working historic building. There will always be a compromise between the comfort of the occupants and the ideal environmental conditions for the contents and fabric.

Consideration should be given to installation of a permanent monitoring system to keep an eye on the internal conditions. This could be linked with the heating system to provide additional control of room conditions. A number of telemetric systems are available that would be suitable for the building.

### **5.1.3 Guys Hospital, London**

#### **1 Background**

Shortly following completion of New hunts house a new modern block to the hospital the basement laboratories and testing rooms were flooded to a depth of 2 meters by a burst water main in the road outside.

Once the water had been removed from the building a process of drying was put into place to bring the building back into use as soon as possible.

The construction of the basement meant that flood water in the building fabric was unable to escape to the exteriors due to damp proofing.

Dehumidifiers were used to dry the basement. The drying progress was monitored by data loggers positioned at numerous points in the basement rooms. This was to monitor the rate of drying and to ensure that the dehumidifiers were providing the optimal drying regime and to check that they were not malfunctioning.

Remedial measures must take into account the effect not only to the historic building fabric but also the contents and occupants.

The techniques used to monitor the internal environment, the fabric and external influences on historic buildings will be discussed.

The instrumentation used and the method of employment of equipment will be discussed.

Measurement of the following parameters will be discussed;

External weather data gathering, masonry moisture monitoring, surface masonry monitoring, Lux and Uv monitoring, tracer gas ventilation rate testing and infrared thermography.

Case studies will be used to describe the techniques used.

Examples of results from the data gathering will be explained and the remedial actions employed based on the results.

**Photograph 9** Resistograph monitoring of timbers in a roof space.

