Assessing the performance of protective winter covers for outdoor marble statuary – pilot investigation

Janet Berry*, Centre for Sustainable Heritage, Bartlett School of Graduate Studies, University College London, Gower Street, London WC1E 6BT Fax: (+44) 2079161887 janet.berry@ucl.ac.uk www.ucl.ac.uk/sustainableheritage

Frances David, Science Museum, Blythe House, 23 Blythe Road, London W14 0QX

Sophie Julien-Lees, Historic Royal Palaces, Apt 59 Hampton Court Palace, Surrey KT8 9AU

Bethan Stanley, English Heritage, 37 Tanner Row, York, North Yorkshire, YO31 7TQ

David Thickett, English Heritage, Room 530, 23 Savile Row, London W1S 2ET

*Author to whom correspondence should be addressed

Abstract

Outdoor statuary in gardens and parks in temperate climates has a tradition of being covered during the winter, to protect against external conditions. There has been little scientific study of the environmental protection that different types of covers provide. This paper examines environmental conditions provided by a range of covers used to protect marble statuary at three sites in the UK. The protection required depends upon the condition of the marble. Although statues closely wrapped and with a layer of insulation provide good protection, this needs to be considered against the potential physical damage of close wrapping a fragile deteriorated surface.

Keywords

marble statuary, protective covers, close wrapping, framed structures, environmental analysis

Introduction

The coverings on outdoor stone statuary aim to provide protection from liquid water, the action of wind, frost, acid pollutants, salt damage, and invasive flora and fauna (Agnew 2001). There are two main approaches to covering statuary. The first is to use framed structures such as wooden boxes (sometimes padded with straw for thermal insulation), metal huts, or tents with heavy-duty tarpaulin or rubberised canvas. The second approach is close wrapping of the sculpture using a range of waterproof materials, which has included industrial aircraft covers and Tyvek ^{TM}. With both techniques, water vapour permeable and impermeable covers have been used. There are perceived advantages and disadvantages to both techniques. Usually the choice of cover balances protective requirements with the operational needs of each individual situation. There has been little scientific research into the protective performance, and microclimatic effects under covers. Initial investigative work in the late 1990s suggested that one cover method in particular could possibly create unwanted microclimatic conditions that could adversely affect the statuary.

A project was undertaken with the aim of providing a coherent decision-making framework for the type of cover to use on marble statuary. Marble was chosen as a stone commonly used for outdoor statues and as a material that suffers from degradation outdoors. The project, involving a partnership of English Heritage, Historic Royal Palaces, the National Trust and University College London, had a number of objectives. This paper will concentrate on the primary objective of determining the environmental performance of different types of covers.

Deterioration of outdoor marble statuary

Winter covers aim to protect statuary from a range of deterioration mechanisms. However, not all materials react similarly to external factors. Therefore, the first step is to assess critically the most important winter conditions from which marble needs protection.

Liquid water has a number of effects. Dissolution of calcite in marble by absorbed carbon dioxide in rainwater is an issue, with Haynie (1983) estimating that 75% of marble loss is from this effect. Simon and Snethlage (1996) found a direct correlation between precipitation and surface roughness of exposed marble samples, with losses of up to 25 microns per year in the worst situations. Dissolution of marble is increased by acidic precipitation from gaseous pollutants.

Water also produces wetting and drying cycles of stone. The low porosity of marble and its high tensile strength make it relatively more resistant to the damage from cycles of wetting and drying and the destructive effects of salt crystallisation cycles (Torraca 1988). However marble becomes more susceptible to this form of damage as it ages.

With winter rainfall projected to increase in the UK (Hulme et al 2002), precipitation will become an increasing factor in the deterioration of outdoor marble statuary.

Another effect of water on marble is freezing. Macro- and microscopic cracks in marble (either present originally in the stone, or formed from other deterioration mechanisms) place marble at risk from frost heave (Torraca 1988). Frost heave occurs in situations where a large pore (such as a hairline crack) is connected to a network of much finer pores. Therefore, porous aged marble is likely to be affected more than less porous newer marble.

A further effect of frost is frost blasting, described by Köhler (1988). Frost blasting again occurs in marbles with greater porosity, but with a low porosity surface layer which prevents water from migrating out of the stone.

Microbiological organisms cause damage to stone through chemical dissolution and precipitation (Laiz et al 2002).Their primary impact may be considered minor compared with other factors (Duffy 1996). However, biological growths are also considered a deleterious aesthetic effect on marble statuary, and their removal through regular cleaning can lead to major surface loss on deteriorated objects.

The extent to which different forms of marble are affected by deterioration mechanisms is influenced by the porosity of the stone. A higher pore volume and larger radii of pores will increase water absorption, thereby increasing surface wetness, leaving the marble more vulnerable to frost damage and biological attack. Rainwashed surfaces will absorb more moisture, increasing the potential for rainwater dissolution over an increased surface area. Furthermore, the increased surface area will increase the potential for chemical dissolution. Therefore, a higher porosity marble in turn makes the marble more susceptible to other deterioration factors.

Therefore protection from rainwater is a major concern for the protection of outdoor statuary during the winter, with freezing an issue for more deteriorated marbles and those with cracks.

Methodology

Trials to test the ability of a range of covers to protect statuary from these factors were undertaken during the winter of 2003/4.

Statues and locations

Marble statues at three sites in the UK were chosen. The sites each had a grouping of similar statues suitable for comparative studies. At each site, the selected statues were of the same stone, of a similar age, had been subjected to similar environmental conditions throughout their life and were located in close proximity to each other. The three sites were chosen to represent different environmental conditions in the UK.

At Anglesey Abbey, in eastern England, a group of early 18th century marble busts, originating in mainland Europe, and now situated in the grounds of the house in a sheltered area since 1953, were selected.

A group of greyhound figures located along the south-easterly aspect of Brodsworth Hall in northern England, were carved from Carrara marble in 1850, and were all exposed to high levels of pollution prevalent in the Yorkshire area in the 19th and 20th centuries.

At Hampton Court Palace in southern England, a group of five classical figures were selected, located in an exposed area close to the River Thames. These Carrara marble figures are late 20th century reproductions of 18th century originals.

Different deterioration patterns were evident between the groups, with the busts showing heavy biological growth and friable surfaces, the greyhounds showing biological growth and surface pitting, and the classical figures showing a sound surface with inherent small defects.

Statue monitoring

Monitoring of covered statues was undertaken from December 2003 to April 2004, to capture the cold and wet conditions of a British winter.

For each statue, the same monitoring protocol was observed, namely monitoring surface temperature, air temperature, relative humidity and surface wetness under each of the statue covers (see figure 1). At each site, the same environmental parameters were monitored on an uncovered 'control' statue, for comparable external data. Data was collected using Starlog surface wetness sensors attached to Smartreader 8 ACR loggers, and either Grant Squirrel or Hanwell dataloggers to record surface temperature, air temperature and relative humidity. Surface temperature and wetness sensors were attached to the surface of the statues using cotton tape.

Before and after the monitoring, spot surface wetness readings were undertaken using a Protimeter Aquant inductance meter.

This methodology allowed investigation of the effectiveness of each cover in keeping water out and buffering against external extremes of temperature and relative humidity, in addition to potential problems caused by microclimates under the covers. To determine whether high moisture levels under the covers were a result of liquid water ingress or condensation, time of wetness was monitored, and percentage of time with condensing conditions calculated from temperature and relative humidity data.

The number of frost cycles was recorded through comparing the surface and air temperature under the cover with the uncovered control statue at each site. Increases in biological activity and deterioration of sculpture surfaces were monitored through condition surveys, including photography before and after covering.

Cover methods and materials

The objectives of the trials were:

- to compare the environments created by the two main types of covering techniques, namely framed structures and close-wrapping;
- to examine the environments created by using water vapour permeable and impermeable materials; and
- to compare the protective properties of a commercially available close-wrapping product and a 'home-made' version.

The types of covers chosen were those which the organisations would typically commission for their sites. At Anglesey Abbey and Brodsworth Hall, where public access is limited in the winter months, experiments were designed to test both framed covers and close-wrapping (see figures 2 and 3). At Hampton Court Palace, which remains open all year round, a variety of close-wrapping methods only were tested (see figure 4). From a presentation viewpoint, close wrapping reveals the form of the statue and is therefore more acceptable for a visitor. Methods which could be manufactured and erected with relative ease were chosen. The types of materials and wrapping regimes chosen are displayed in table 1.

Results and discussion

Water ingress

Chemical dissolution is a major factor for marble, and hence protection against water should be a main function of a protective cover. The monitoring data demonstrates that the water vapour permeable closewrap with insulation provided the best protection against surface wetness. Of all the covers, only the water vapour permeable closewrap at Brodsworth Hall (with and without insulation) provided drier conditions than the uncovered statues (see table 2). Statues under framed structures and Cliveden Winter Covers were wet for between 78 and 85% of the time at all sites, yet differed in their number of wet/dry cycles. Most covers, to different extents, appeared to inhibit evaporation and retain water on the surface of statues.

In general under most covers, conditions were conducive for condensation for approximately 15 to 20% of the monitoring period. Under the water vapour permeable tent and closewrap with insulation at Brodsworth Hall, the time for condensation was less. This suggests that breathable properties are important for covering materials, and incorporation of insulation provided a hygroscopic buffer.

All the covers protected against the extremes of RH fluctuations to varying degrees (see figure 5). The absolute humidity under the wraps with insulation was generally higher than under the framed structures, and external conditions (figure 6).

A comparison of the wetness and condensation data suggests that as conditions for condensation existed for 15-20% of the time, whilst the time of wetness was significantly greater, much of the moisture was water from rain events.

Frost protection

Statue wetness combined with freezing temperatures may lead to freeze-thaw damage of statues. Maintaining temperatures above freezing is an important aspect of the protection covers can provide. At all sites, ambient temperatures fell below 0C on a number of occasions during the winter. Of the covers tested, the Cliveden Winter Cover provided the most effective protection from freezing cycles (see figure 7). This was followed by the water vapour permeable closewrap with insulation. The framed structures provided similar thermal protection and performed better than the water vapour permeable wrap without insulation, and Tyvek.

However, analysis of the incidents where statues were simultaneously wet and at temperatures below 0ºC under a cover reveals that the water vapour permeable closewrap with insulation created fewest incidents. In general, the close-wrapped statues were less likely to be wet during periods below 0C.

Therefore, the water vapour permeable closewrap with insulation, although not providing as much thermal protection as the Cliveden Winter Cover, provided good freeze-thaw cycle protection as it maintained a drier stone surface during freezing periods.

Biological activity

During the period of monitoring, there was no noticeable difference between the amount of biological activity on the uncovered and covered statues at all sites. However, observations of statues that are regularly covered at Brodsworth Hall indicate that over a period of 5 years, biological growth on covered statues was noticeably lower than on uncovered statues. It will be interesting to observe over time whether the increased dampness under some covers provides a source of moisture that encourages biological agents. Insects and small mammals demonstrated no preference for framed or close-wrapped statues, living under all covers.

General discussion

Considering the deterioration of marble, the factors for which covers are appropriate depend upon the morphology and deterioration state of the marble. For new marble with very low porosity, freeze-thaw cycles are less of an issue than for damaged marble with higher porosity.

There is discussion as to whether framed structures provide better protection than close-wrapping. One of the arguments for using framed structures is to encourage airflow around the statues, thus minimising the amount of time that the statue remains wet. Framed structures also do not touch the object, thereby limiting physical damage. In general, the air under the framed structures did provide greater mixing with external air, with absolute humidities similar to external conditions. However, this mixing did not keep the surface of the stone drier than the statues closewrapped with the water vapour permeable covers.

Conclusions

This paper discusses the environmental conditions provided by each of the tested covers. From this data, it can be seen that close-wrapping of statues using a method involving insulation (water vapour permeable cover with insulation or Cliveden Winter Cover) appeared to provide good protection from freeze-thaw cycles, and stable humidity level, albeit generally higher than external absolute humidity levels. Framed structures provided better frost protection than for statues with no covers at all. Of concern for most covers tested was the increase in wetness under the covers as opposed to uncovered statues. However, all covers protect from the washing of surfaces from rain.

During the winter of 2004, monitoring will be repeated to verify the results. Future trials will analyse the composition of the water on the surface of statues at the end of the winter, to determine the amount of chemical dissolution that has occurred.

When covering statues, environmental conditions are just one of many factors that need to be taken into consideration. Close-wrapping involves close physical contact with the stone surface, where care is needed if the surface is friable. The aesthetic appearance of the covers, their initial and maintenance costs, and summer storage also need to be considered.

A risk matrix is being developed, to enable the environmental data to be placed within the context of the wider decision-making process. This matrix will form the basis of guidance notes for sites within the organisations taking part in this project.

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Endnotes

[1] The Cliveden Winter Cover is a cover comprising of 3 layers (a permeable inner layer, a thermal lining and an impermeable outer layer. The cover is made to order, to ensure a close fit to the statue.

[2] The impermeable tents were constructed with vents, as this is a common approach o enhance ventilation.

[3] Blank spaces in table 2 indicate data not available due to equipment failure.

[4] Monitoring period for the Cliveden Winter Cover was 99 days.

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Materials list

Grant Squirrel datalogger Grant Instruments, (Cambridge) Ltd, 29 Station Road, Shepreth, Cambridgeshire, SG8 6GB, UK

Hanwell 3-channel datalogger Hanwell Instruments Limited, 12-13 Mead Business Centre, Mead Lane, Hertford SG13 7BJ, UK

Starlog surface moisture detector Unidata, Unit 2, Turner Business Park, Sheffield, S13 8HT UK

Smartreader 8 ACR loggers

Protimeter Aquant inductance meter Protimeter PLC, Meter House, Fieldhouse Lane, Marlow, Bucks, SL7 1LW, UK

P13 waterproof heavy polyurethane coated nylon Pennine Outdoor, 2 Station Road, High Bentham, North Yorkshire, LA2 7LF, UK

P32 polyurethane-coated polyester microfibre Pennine Outdoor, 2 Station Road, High Bentham, North Yorkshire, LA2 7LF, UK

Quilters Dream Poly™ polyester wadding The Cotton Patch, 1285 Stratford Road, Hall Green, Birmingham, B28 9AJ, UK.

Cliveden Winter Cover Cliveden Conservation Workshop Limited, The Tennis Courts, Cliveden Estate, Taplow, Berkshire, SL6 0JA UK

Tyvek TM Preservation Equipment Ltd, Vinces Road, Diss, Norfolk IP22 4HQ UK

Table 1 Types of covers tested at each site

			Anglesey Abbey	Brodsworth Hall	Hampton Court Palace
Close-wrap	Water vapour permeable covers	P32 polyurethane-coated polyester microfibre	X	X	X
		P32 polyurethane-coated polyester microfibre with underlayer of Quilters Dream Poly™ polyester wadding	X	X	X
		Tyvek ™			X
	Water vapour permeable interior / impermeable exterior	Cliveden Winter Cover [1]	X	X	X
Framed structures	Water vapour permeable cover	P32 polyurethane-coated polyester microfibre	X	X	
	Water vapour impermeable cover	P13 polyurethane coated nylon [2]	X	X	
Control		No cover	X	X	X

Table 2 Results from monitoring data [3]

Cover Type	Period surface wet (%)	Number of wet/dry Cycles	Period condensation possible (%)	RH range (%)	Temperature range (C)	Number of freeze/thaw events	Number of wet and freezing events
Anglesey Abbey (106 days monitoring)							
Control (no cover)	28	122					
Water vapour permeable closewrap	86	18					
Water vapour permeable closewrap with insulation	42	49					
Cliveden Winter Cover			16	53- 98	-2 to 14	10	
Water vapour permeable tent	83	38					
Impermeable tent	84	31					
Brodsworth Hall (126 days monitoring [4])							
Control (no cover)	44	225	3	29-100	-5.5 to 20.5	34	20
Water vapour permeable closewrap	27	72	16.2	47-100	-4 to 15.5	28	5
Water vapour permeable closewrap with insulation	27	29	12.5	48-100	-3.5 to 14	14	3
Cliveden Winter Cover	85	20	23	90-100	-2.5 to 12	4	4
Water vapour permeable tent	80.5	67	2.4	50-100	-3 to 16.5	17	14
Impermeable tent	80	64	18	37-100	-3 to 17	14	10
Hampton Court Palace (113 days monitoring)							
Control (no cover)				24-100	-3.5 to 18	23	
Water vapour permeable closewrap			20	48-100	-2.5 to 16	15	
Water vapour permeable closewrap with insulation	54	91	19	45-100	-1 to 15.5	11	4
Cliveden Winter Cover	78	17	17	38-100	-1 to 16	11	10
Tyvek closewrap	63	11	20	51-100	-3 to 15	20	11

Figures

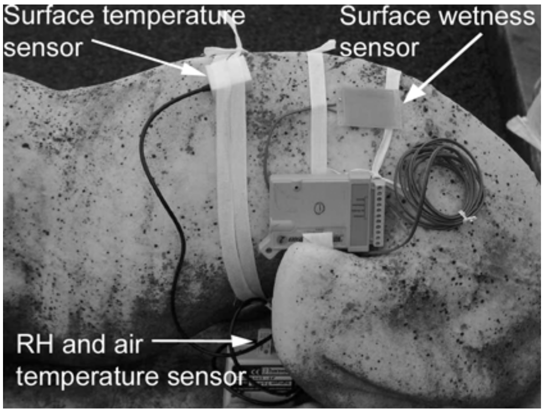

Figure 1 Monitoring equipment installed on marble greyhound, Brodsworth Hall

Figure 2 Covering of marble greyhound, Brodsworth Hall, with P13 polyurethane coated nylon impermeable tent (view of frame with and without cover)

Figure 3 Close wrapping of marble bust at Anglesey Abbey with the Cliveden Winter Cover (front and back view)

Figure 4 Close wrapping of marble statues at Hampton Court Palace with (a) water vapour permeable close wrapping and (b) water vapour permeable close wrapping with insulation

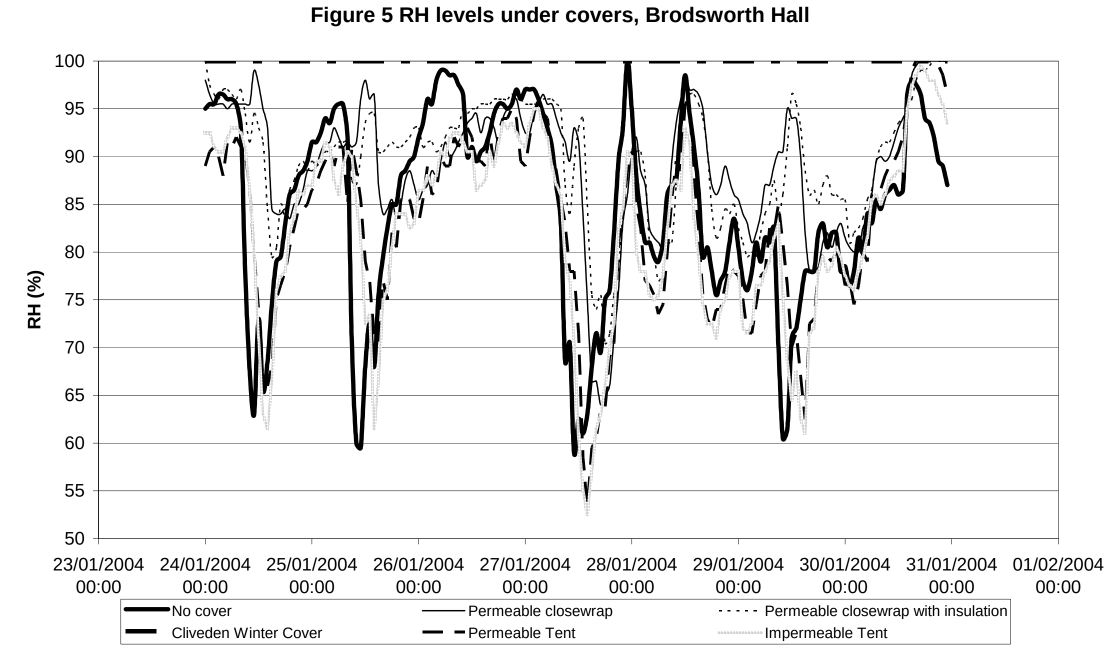

Figure 5 Relative humidity levels under covers, Brodsworth Hall

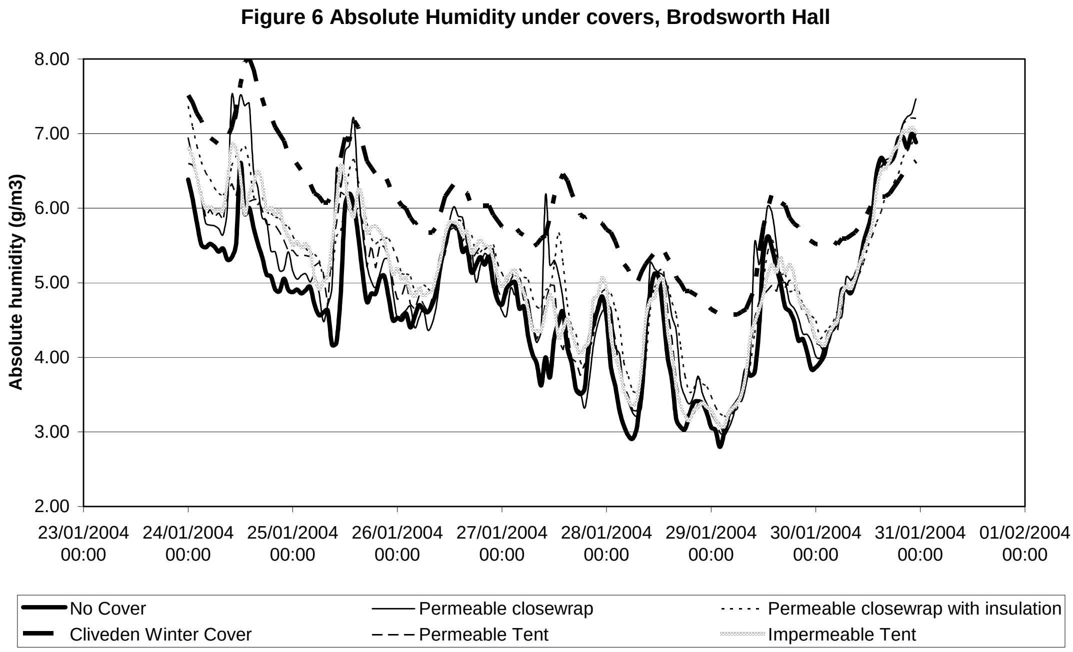

Figure 6 Absolute humidity levels under covers, Brodsworth Hall

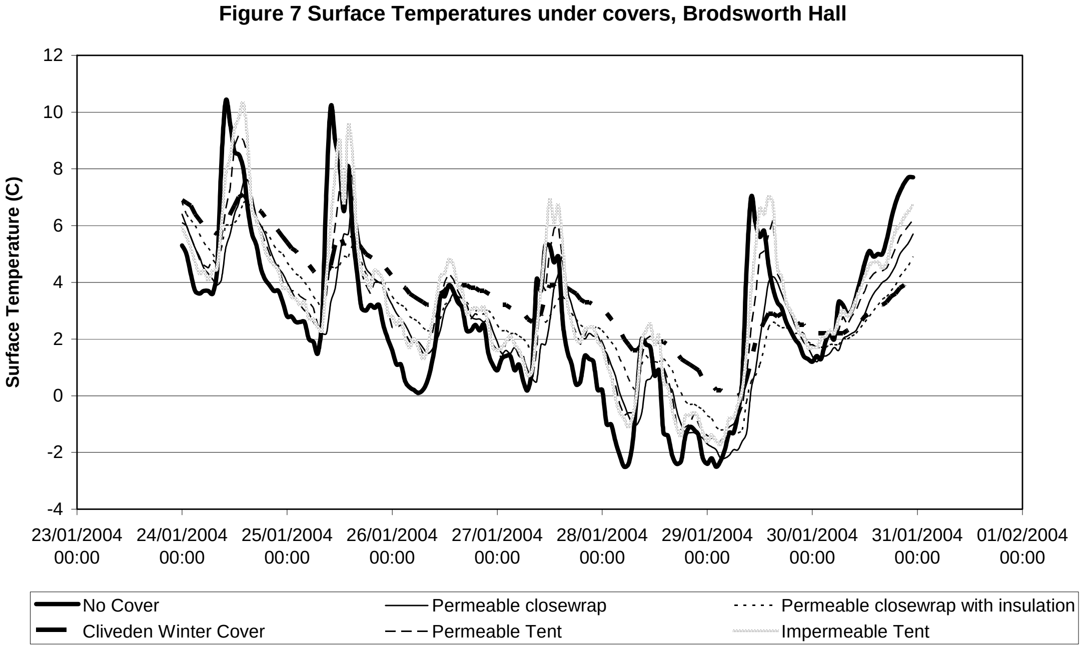

Figure 7 Surface temperature levels under covers, Brodsworth Hall