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WINTERTON HOUSE, LONDON: ANALYSIS OF TEMPERATURE DATA

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Abstract

The main findings are presented of an analysis of temperature data obtained from the monitoring of Winterton House, a 26-storey steel frame building that was reclad with a novel form of 'off-the-frame' clay brickwork. The analysis found that, at any instance, the temperature of the brickwork on the four elevations of the building varied by between 0.2°C and 17.6°C, whilst a temperature gradient of up to ± 6.5°C occurred across the 655mm thick brickwork at the base of the building. In any month the height of Winterton House varied by up to 15mm in response to changes in the ambient temperature. A thermal lag of 3 to 4 hours also occurred between the external air temperature and the temperature of the brickwork.

Key Words

Brickwork, cladding, temperature

1 Introduction

Winterton House is a 26-storey steel frame building in the Tower Hamlets district of London that was originally constructed in the 1960's and subsequently reclad with a free standing skin of off-the frame clay brickwork in the mid 1990's (Figure 1).

Figure 1 Winterton House

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To prevent long-term differential movement, the steel frame and brickwork cladding were locked together at roof level by a steel transfer mechanism (Figure 2). It was anticipated that this type of hybrid construction, which involved applying a prestress to restrain the brickwork at roof level, would enable compressive load to be transferred out of the steel frame and into the brickwork. As such the brickwork would contribute to the load carrying capacity of the structure (Bird and Hitchens, 2000).

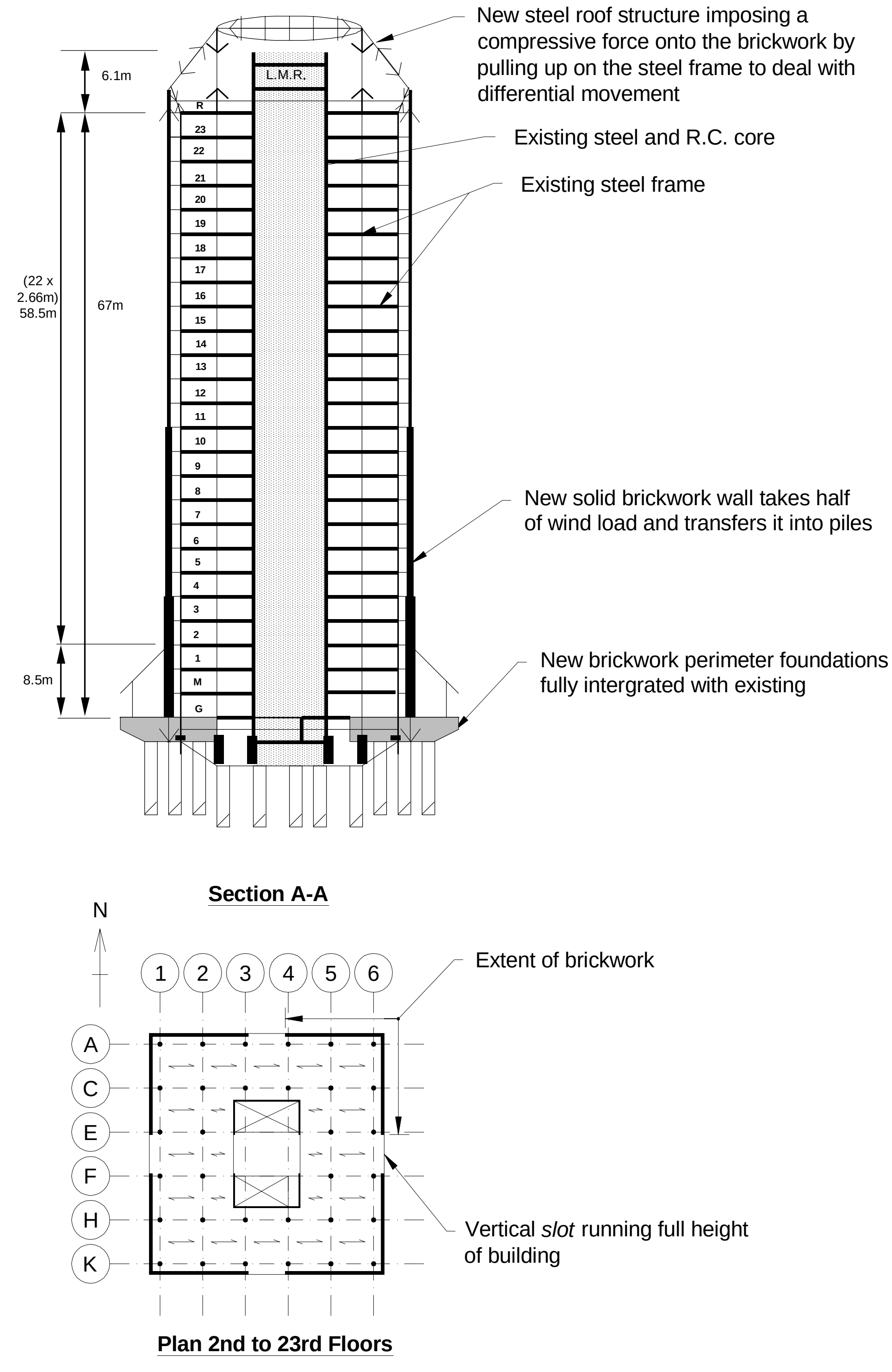

Figure 2 Details of Winterton House

During the refurbishment, which took place between 1995 and 1997, a limited number of strain gauges and thermocouples were installed on the building and monitored. In early 1998 additional instrumentation was added and the monitoring period extended a further year. It was anticipated that the data obtained from this instrumentation would provide a better understanding of the building's actual behaviour and enable initial design assumptions to be verified so that this type of composite construction could be used more widely.
One aspect of particular interest was the range of temperature to which the finished brickwork would be subjected as the UK code of practice for the design of structural masonry (British Standards Institution, 2001) gives only general advice on this and simply recommends that an estimate of the likely range of temperature be made. At the design stage maximum and minimum brickwork temperatures of + 40ºC and -5ºC were chosen, based on a careful review of the available literature and advice from brick manufacturers.
A thorough analysis of the temperature and strain data from Winterton House has now been carried out under a separate project (Department of the Environment, Transport and the Regions, 2001) and details of the long-term stress/strain interaction between the steel frame and the restrained brickwork cladding published (Bingel et al, 2003). This paper presents the principal findings from the analysis of the temperature data.

2 Instrumentation

A single temperature-compensated electrical resistance strain gauge and thermocouple were attached to the inner face of a perimeter steel column on the four elevations of the building at the ground, 13th and 21st floor levels i.e. columns A9, H11, K3 and C1 in Figure 2. A second thermocouple was positioned approximately 50mm in from the inner face of the brickwork immediately adjacent to each of these columns. The thickness of the brickwork at the ground floor level was 655mm, whilst at both the 13th and 21st floors it was only 215mm thick. A number of strain gauges and thermocouples were, in fact, attached to the steel transfer mechanism at roof level, but as these failed to function correctly, those data had to be discarded
In 1998 an additional set of thermocouples were positioned within the east face of brickwork at the mezzanine level only in order to measure temperature gradients across the thicker brickwork at the base of the building. These were placed in a line at 75mm centres horizontally and at depths of 100mm, 150mm, 330mm, 440mm and 550mm from the outer face of the 655mm thick brickwork (Figure 3).

Number of thermocouple	Depth of gauge
2	100 mm
3	150 mm
4	330 mm
5	440 mm
6	550mm

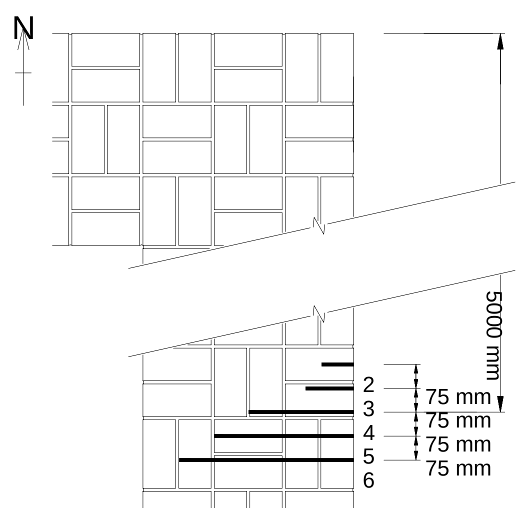

Figure 3 Details of thermocouple cluster at mezzanine floor level

The external air temperature was measured using a single thermocouple positioned on the south elevation at the 21st floor level, although its precise position i.e. whether in direct

sunlight or shade, was unknown. The measured values therefore could only be considered as an 'indication' of the actual air temperature as the possible effects of solar radiation on the thermocouple could not be quantified. Strain and temperature readings were taken every few seconds over the three-year monitoring period and downloaded to a central datalogger.

3 Discussion of results

3.1 External air temperature

Table 1 shows the maximum and minimum air temperatures recorded by the thermocouple on the south face at the 21st floor. The maximum of 40.6ºC is, in fact, higher than the official record for the hottest day ever in Britain (38.5ºC) and is probably influenced by radiant heat from the building itself and the possible effects of solar radiation as outlined above.

Table 1 Extreme values of temperature

	Minimum - before occupation (ºC)	Minimum - after occupation (ºC)	Maximum (ºC)
External (air)	-0.7	1.0	40.6
Brickwork	-4.4	0.1	33.4

A comparison of the maximum and minimum daily air temperatures at Winterton House during the month of August 1998 with those at Heathrow Airport, which is approximately 25 miles to the west showed that, whilst the same pattern of temperature variation occurred, the air temperatures recorded at Winterton House were typically between 5ºC and 10ºC degrees higher.

3.2 Brickwork cladding temperatures

3.2.1 Maximum & minimum temperature

The maximum and minimum temperatures recorded in the brickwork cladding over the three-year period were 33.4ºC and -4.4ºC, respectively (Table 1). The maximum was recorded twice: once on the 13th floor of the west face, and on the 13th floor of the east face. In the case of the west facing brickwork the maximum occurred at 8pm in the evening when the air temperature, as measured on the 21st floor of the south face, was 29.6ºC. In the case of the east facing brickwork, the maximum temperature was recorded at 3pm in the afternoon, when the external air temperature was 36.1ºC, again measured on the 21st floor of the south face.

The minimum temperature of the brickwork, -4.4ºC, was recorded on the 21st floor of the west face at 11a.m., before the refurbishment had actually been finished. The external air temperature at this time was 0.3ºC. Once the building had been completed and re-occupied, the minimum temperature occurring in the brickwork was 0.1ºC. This occurred at the 21st floor of the north face.

Figure 4 shows the monthly range of temperatures recorded in the brickwork cladding over the three-year monitoring period.

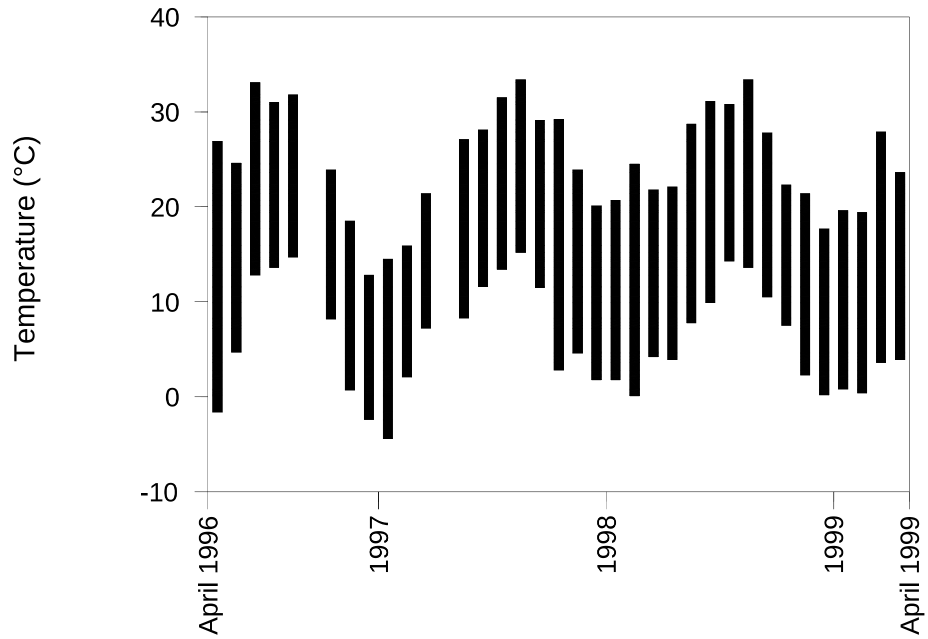

Figure 4 Monthly range of temperature for the brickwork cladding

3.2.2 Warmest and coldest elevations

An analysis of the data from the thermocouples on the ground, 13th and 21st floors of each elevation showed that the south face of brickwork was, on an annual average basis, the warmest and that the west or the north face was the coldest.

3.2.3 Variations in brickwork temperature between elevations

Analysis of the data found that the temperature of the brickwork on the four elevations varied by between 0.2ºC and 17.6ºC at any instance. The maximum difference of 17.6ºC occurred at 7pm one evening in November, when the temperature of the brickwork on the north face at the ground floor was 6.3ºC and the temperature on the 21st floor of the south face was 23.9ºC. The minimum of 0.2ºC occurred at 12noon one day in December, when all the thermocouples recorded temperatures between 7.4ºC and 7.6ºC. No overall pattern to the variations in temperature between the different elevations was evident, however.

3.2.4 Temperature gradient across brickwork

As previously explained a series of thermocouples were positioned at various depths in the east facing brickwork at the mezzanine floor level, where the brickwork was 655mm thick. On an annual basis, the average temperature difference across this thick brickwork was ±1ºC, with maximum differences of approximately ±6.5ºC. Figure 5 shows the distribution of temperature through this brickwork under the maximum temperature differences. The differences in temperature between the external and internal faces of the brickwork would, presumably, have been higher than those shown in Figure 5.

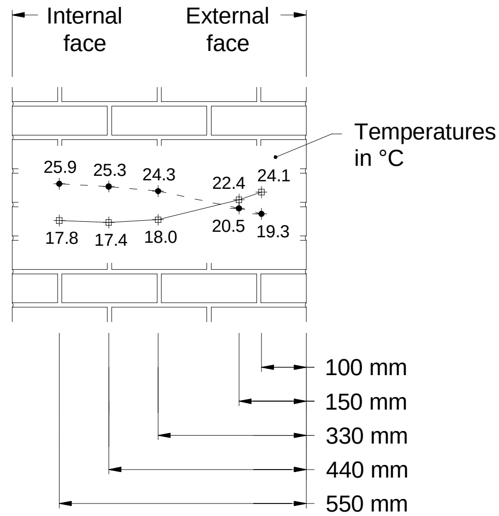

Figure 5 Maximum temperature gradient across thermocouple cluster at mezzanine floor level

Data on temperature gradients across the 215mm thick brickwork were not available, as thermocouples were only positioned 50mm in from the inner face. In previous tests on Fletton cavity wall brickwork exposed to the weather (Beard et al, 1966), temperature differences of up to 17ºC (30ºF) were recorded across a south-facing 102mm leaf of brickwork. The maximum differences in temperature across the 215mm brickwork at Winterton House would, therefore, probably have been higher than those recorded across the 655mm brickwork at the mezzanine level, although this could not be confirmed.

3.2.5 Thermal lag

Analysis of the data showed that a thermal lag occurred between the external air temperature and the temperature of the brickwork cladding, the brickwork temperature typically lagging three to four hours behind the air temperature. Prior to the building being occupied, a thermal lag of several hours also occurred between the external air temperature and the temperature of the perimeter steel columns. Once the building was occupied, the thermal lag between the steelwork and the external air temperature increased to several days.

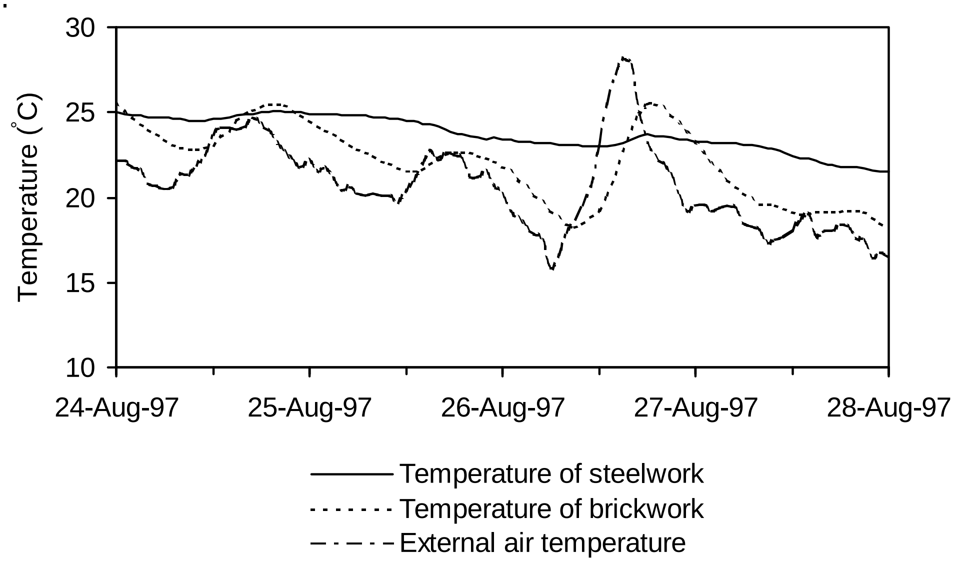

Figure 6 Thermal lag

3.3 Change in height of building due to temperature changes

The strain gauge data showed that, in any month, the height of the building varied by between 10mm and 15mm in response to changes in the ambient air temperature, and that the building was slightly shorter during the winter than the summer. In addition, it was found that thermal movement of brickwork around the building was not uniform. For example, during the day one elevation could expand whilst another was simultaneously contracting as the temperatures on the two elevations gradually increased and decreased, respectively. Equally, two or more elevations could expand, or contract, by different amounts according to the brickwork temperatures on each elevation. These short-term differential movements between elevations were small, however, typically ranging from 2mm to 5mm under the temperatures encountered at Winterton House.

4 Conclusions

Analysis of the data obtained from the limited number of thermocouples and strain gauges installed on Winterton House revealed the following;

1. The maximum and minimum external air temperatures were 40.6ºC and –0.7ºC, measured at the 21st floor level of the south face.
2. The maximum and minimum temperatures recorded in the brickwork were 33.4ºC and –4.4ºC, respectively. Surface temperatures of the brickwork were probably higher and/or lower than these values, although this could not be confirmed from the limited data available.
3. Based on annual average temperature the south elevation of the building was the warmest, with either the north or west face coldest.
4. At any instance the temperature of the brickwork on the four elevations of the building varied by between 0.2ºC and 17.6ºC. No patterns to these variations in temperature were evident, however.
5. The maximum temperature difference recorded at the mezzanine floor level was ±6.5ºC. The difference in temperature between the internal and external faces of the brickwork at this level would probably have been higher, although this could not be confirmed.
6. A thermal lag of three to four hours existed between the external air temperature and the temperature of the brickwork cladding.
7. Prior to the building being occupied, a thermal lag of several hours occurred between the external air temperature and the temperature of the perimeter steel columns. Once the building was occupied, this increased to several days.
8. In any month the height of Winterton House changed by between 10mm and 15mm in response to changes in the ambient temperature.
9. Short-term changes in the brickwork temperature around the building resulted in differential movement between the brickwork on different elevations. These movements were small, however, typically ranging between 2mm and 5mm.

5. Acknowledgement

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6. References

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