SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 11, No. 1, (2025), pp. 15-26
Open Access. Online & Print

DOI: 10.5281/zenodo.14274643

UNLOCKING THE FUTURE OF YORK'S HISTORIC BUILDINGS: SUSTAINABLE STRATEGIES AND INNOVATIVE CONSERVATION DECISION MAKING

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Received: 07/10/2024
Accepted: 03/12/2024
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ABSTRACT

This paper delves into the realm of sustainable approaches to preserving the rich built heritage of York, United Kingdom. York has retained a remarkable legacy of historic buildings, understanding how these buildings continue to adapt through time is essential for successfully managing their change into the future. Our research endeavours to fuse social context with material data, crafting holistic methodologies that honour the past while catering to the needs of present and future generations. In alignment with the ethos of sustainable conservation, our project champions minimal intervention practices, echoing the sentiment that "the greenest building is one that is already built" (Elefante, 2007). Through this work, decision-making strategies for these exceptional structures can be embedded with resilience, serve the needs of people today and in the future, and respect the original intentions of their creators. Focusing on a unique structure nestled in York's city centre, our case study showcases a collaborative effort between the York Conservation Trust and the University of York Department of Archaeology. Following work to restore the exterior lime rendering, environmental data loggers were placed throughout the building for approximately one year of data collection before further decisions on building adaptations were considered. The opportunity of having a minimally disturbed data set from in this context was a unique and exciting opportunity. By correlating environmental data with structural assessments and historical research, stakeholders can make informed decisions regarding adaptive reuse, restoration techniques, and ongoing maintenance protocols. This evidence-driven approach enhances the efficacy and sustainability of conservation interventions, fostering a harmonious coexistence between the built environment and its natural surroundings. Our findings illuminate a path forward, showcasing the viability of a minimally interventive approach to preservation.

KEYWORDS: Conservation, Built Heritage, Environmental Monitoring, Sustainability, Decision-making

1. INTRODUCTION

York, a city renowned for its rich legacy of historic buildings, stands as a testament to centuries of architectural achievement. Preserving the city's built heritage is not only essential for maintaining its unique character but also for ensuring that future generations can engage with its past. As the pressures of modernisation grow, balancing the preservation of York's historical structures with the demands of contemporary life has become an increasingly complex challenge. At the heart of this challenge lies the question: how can we sustainably manage historic buildings, ensuring they serve modern needs without compromising their historical integrity?

This paper explores an underpinning strategy for managing York's historic buildings, focusing on the intersection of conservation, minimal intervention, and contemporary functionality. As York continues to evolve, it is critical to understand how its historic structures can adapt to changing environmental and social conditions while maintaining their original character. By examining one of York's historic buildings, this study showcases a collaborative effort between the York Conservation Trust (YCT) and the University of York's Department of Archaeology. Together, we explore how to embed decision-making processes that prioritise sustainability more efficiently and pragmatically approach adaptive reuse. *Adaptive reuse* in this context explores the modification of heritage buildings in terms of social and architectural elements (Arfa *et al.* 2022). This research serves as a pilot study for a larger undertaking across the city, aiming to demonstrate how York's historic buildings can continue to thrive avoiding disuse, reflecting both the intentions of their creators and the needs of today's society. The aim of this study is to understand the current environment in one of York's historic structures, 60 Goodramgate, and the extent to which further intervention at the site was necessary for it to be utilised as a retail space. For this research, an environmental monitoring program was implemented at the site, examining temperature and relative humidity (RH). The environmental data collected for the case study looks to understand the current conditions within the property to underpin further decision-making regarding modifications to the internal environment for it to be a viable retail space, with user comfort as a key consideration.

2. RESEARCH CONTEXT

2.1 *Environmental Risks to Historic Structures in the UK*

Buildings are constantly exposed to dynamic environmental changes—external factors like time of day, seasons, and weather, as well as internal factors such as usage. To endure the building envelope must adapt, maintaining a 'dynamic equilibrium' (English Heritage, 2014). Moisture is a key cause of deterioration, as most traditional materials are permeable and contain moisture. For example, while timber thrives with 16-18% moisture content, it decays with levels above 20%, triggering dry rot, or succumbs to wet rot in persistently damp conditions (Singh, 1996). Prolonged relative humidity (RH) above 70-80% or direct exposure to moisture can encourage mould growth in materials, with condensation as the main source of this moisture in buildings (Douglas and Ransom, 2013). High humidity and condensation are also damaging to other building materials. For example, poor drainage can saturate brick walls, ultimately leading to structural damage (Park, 2009). Moisture also accelerates corrosion in metals, particularly ferrous alloys, which expand and crack surrounding materials (English Heritage, 2012).

While global challenges with dynamic environments are impacting the historic environment, York, like many cities in the UK suffers from the impacts of water damage via heavy precipitation and regular flooding. Temperature fluctuations heighten these risks by accelerating chemical reactions, increasing evaporation, and affecting material dimensions (Allen, 2005). Changes in temperature and moisture levels can cause brick and mortar to undergo cycles of expansion and contraction, gradually weakening them and increasing susceptibility to salt crystallisation and frost damage (Doehne, 2002). Harris (2001) offers extensive insight to the wider complexities of understanding building pathology. Ultimately, the intricate balance of moisture and temperature plays a critical role in the longevity of building materials.

2.2 *Understanding Building Decay*

Early methods of building preservation were reactive, focusing primarily on repair or reconstruction after damage, rather than proactive management and preventive conservation. Jokilehto (2017) provides a comprehensive analysis of the evolution of conservation philosophy, addressing how early preservation efforts were largely driven by an emotional or reactionary response to the deterioration of heritage buildings, rather than guided by formalised principles or proactive management. While the work of Morris and SPAB promotes staving off decay through "daily care" (Morgante, 2024), the landscape of maintenance in the historic environment has grown to embrace preventative measures and monitoring systems (Rosina, 2018).

There are a range of tools and techniques available to understand the environment of historic buildings

(Rossi and Bournas, 2023). Laser scanning and infrared thermography help identify structural issues like moisture infiltration, voids, or cracks and these tools provide precise data about a building's condition, enabling targeted repairs and reducing unnecessary interventions (Adamopoulo and Rinaudo, 2021). Seismographs or accelerometers are used to detect vibrations from nearby construction, traffic, or even foot traffic, which within a building can lead to damage, particularly fragile structures or decorative elements (Costanzo *et al*. 2022). Poor air quality, including high levels of pollutants like sulphur dioxide, nitrogen oxides, and particulate matter, can accelerate the decay of historic surfaces. Monitoring the concentration of these pollutants helps in mitigating their impact by improving ventilation or installing air filtration systems (Camuffo, 2019). Light, especially ultraviolet (UV) radiation can fade wallpaper, textiles, and other light-sensitive materials. In naturally lit buildings, the light, UV, and near-infrared (NIR) levels also vary strongly (Thickett, 2023). Light sensors and UV metres measure the intensity and type of light in the building. Limiting exposure to natural and artificial light through protective glazing or UV filters can help preserve sensitive materials (Staniforth, 1992).

Understanding trends in temperature and RH in historic buildings is essential to preserving their structural integrity and materials while maintaining optimal conditions for occupants and artefacts (Thickett, 2023). Monitoring devices like dataloggers continuously track temperature and RH levels. However, assessing monitored environmental data in naturally ventilated buildings is complex, with temperature, RH, and both gaseous and particulate pollution levels varying over several periods and frequently with strong seasonal variations (Camuffo, 2019). Maintaining a relatively stable environment helps limit material degradation, cracking, or mould growth. According to Brimblecombe and Richards (2022), keeping RH between 40% and 60% is ideal for most historic materials in temperate climates. Monitoring the presence and distribution of moisture is useful to support the choice of the most appropriate intervention, reducing the risk of applying ineffective, unnecessarily costly, or excessive interventions (Rosina, 2018).

2.3 Considerations in the Sustainable Conservation of Historic Buildings

Sustainability in conservation carries a variety of meanings, from environmental impact to resource depletion and social relevance, navigating sustainable decision-making involves complex and on-going considerations. One of the recurring issues for all buildings in the UK and Europe is reducing carbon emissions (PD CEN ISO/TR 52000-2:2017), which now carries political, economic, and social implications. Traditional buildings face pressure to improve energy efficiency without harming their architectural or historic significance via a whole building approach (Menconi *et al*., 2024). The challenge lies in balancing necessary alterations for efficiency with preserving a building's heritage to avoid diminishing its value (Godwin, 2011). The response to climate change drives a number of considerations within the built heritage sector as site managers tackle difficult realities of mitigation, adaptation, and resilience (Woodward and Cooke, 2023). The focus on reducing carbon emissions has been largely driven by the Kyoto Protocol of 1997, which committed nations to cut emissions across all sectors (Lockwood, 2021). This has resulted in legislation from both the European Union, with the Directive on the Energy Performance of Buildings (EU/2024/1275), and the UK Government, through the Climate Change Act of 2008 (Curtis, 2010). More recently the National Planning Policy Framework (2023) Section 14 and Historic England guidance on Adapting Historic Buildings for Energy and Carbon Efficiency (2024) highlight the UK's proactive approach to climate change.

A key aspect of sustainable decision-making in the conservation of the historic environment is that of minimal intervention (Turk *et al*., 2019). A key consideration of minimal intervention in heritage conservation emphasises preserving the authenticity and integrity of historical structures by limiting the extent of restoration or alteration. It is guided by the idea of "doing as little as possible, but as much as necessary", ensuring the original fabric and character of heritage sites remain largely untouched (Jokilehto, 2017). This philosophy prioritises conservation techniques that allow for re-treatability, allowing future interventions as technology and knowledge evolve. The Burra Charter (1979) is one of the first documents referring to minimising the effect of conservation activities on the material fabric (Article 7) and gained traction in subsequent decades (Zhang and Dong, 2021).

2.4 Contextualising People in Old Buildings

The British Standards Institute (BSI) defines thermal comfort as an individual's perception of their body's overall thermal balance (BS EN ISO 7730). However, due to variations in personal preferences, it is impossible to establish universally optimal thermal conditions. Furthermore, thermal conditions may not always be the primary factor influencing human comfort. Research indicates that individuals often prioritize other factors, such as air quality or acoustic conditions, especially when these become intolerable (Frontczak and Wargocki, 2011). This makes it difficult to prioritise environmental conditions, though it does indicate that people are more likely to put up with suboptimal temperatures than poor air quality or excessive noise. Government guidelines are also ill-defined; the Health and Safety Executive recommends a minimum working temperature of 16°C (or 13°C for strenuous work), but no maximum temperature is stipulated (Bollans and Preece, 2024). Naturally managed temperatures tend to require less heating or cooling, and individuals acclimated to warmer or cooler environments experience a broader range of comfortable conditions (Rupp *et al*., 2015). Factors like the thermal conductivity of walls, moisture permeability, window arrangement, and room layout/dressing significantly impact comfort (Zheng *et al*., 2022). These elements, though harder to modify in historic buildings, play a critical role in determining thermal comfort in temperate climates.

Dampness in buildings is a major health risk, aggravating conditions such as asthma, angina, arthritis, rheumatic pain, blood flow problems, chest infections, and coughs (Douglas, 2006). Mould spore and bacterial growth, encouraged by dampness, can produce an allergic response on the skin or act as an irritant in the respiratory tract (Sing, 2001). Moulds such as Penicillium chrysogenum and Aspergillus fumigatus are toxic, whilst Alternaria alternata and Cladosporium cladosporioides are moulds that are typically allergenic (ibid). While much of the research in this area focuses on domestic contexts, adverse health effects of dampness are also possible in non-residential buildings. The work of Karvala *et al.* (2010) found a correlation between higher rates of adult-onset asthma and sick days related to a damp and mouldy work environment.

3. MATERIALS AND METHODS

3.1 Research Design

This research focuses on the site of 60 Goodramgate to inform its renovation and suitability for future retail use. The building's performance was analysed in relation to its ability to maintain comfortable thermal conditions year-round, how effectively the internal environment is buffered against the external weather conditions, and whether internal conditions pose a threat to building materials. Data collected included temperature, RH and dew point. The work comprises primary environmental data collection at the site from the period of 21 June 2023 to 24 April 2024. The YCT agreed to a year of data collection before further decisions on building adaptations were considered. To monitor the environmental conditions of 60 Goodramgate, 13 Gemini TinyTag Plus 2 (TGP 4500) data loggers were installed in the property (Figure 3). The loggers were last calibrated by the manufacturer, 31 May 2023, less than one month before the study began. These loggers offer data accuracy of ±o.4°C and ±3.0% RH in the conditions that occurred over the course of this study (Gemini 2019). The loggers were placed in the most southern portion of each room as feasible, there were access considerations needed so some adjustments were made to minimise the risk of the loggers being moved. The loggers were set on platforms 10cm above the floor to limit dust contamination. Logger sensors were set facing into the centre of the room. The loggers collect environmental conditions at set intervals of every 30 minutes. This information is valuable for understanding environmental conditions, assessing the need for heating, ventilation, and air conditioning (HVAC) systems, and optimising environmental control strategies, as none currently exist at the property. The YCT recognised the value in having underpinning data on the environment while they considered the further alterations to the building, particularly environmental modification systems.

4. CASE STUDY: 60 GOODRAMGATE

60 Goodramgate exemplifies a rich intersection of history and architecture, originating from two distinct structures deeply rooted in York's heritage (Figure 1). This building serves as an ideal case study for this research due to its architectural complexity and historical significance. The origins of the building are contested, by some accounts the building stands as part of the earliest surviving examples of timber-frame jettying in the UK, though this association may have been incorrectly attributed (Smith, 2021). Portions of 60 Goodramgate were rebuilt in the late 18th century, with further modifications occurring in the 19th and 20th centuries, reflecting York's capacity for adaptation and resilience. Currently, the structure is a combination of timber-framing and brickwork, with rendered facades, and a dual roofing system of tile and slate. Notably, the chimney stacks have been removed (Figure 2).

Internally, much of the medieval structure remains intact, with features such as dragon beams, corbels, and jettying now exposed. Several late 19th-century fireplaces have survived, and the original low roofline is visible in the upper rooms (Smith, 2021). Historically, the small tenements along Goodramgate housed shops on the ground floor with living spaces above. Recent restoration efforts by the (YCT) uncovered evidence of 18th and 19th-century decorative schemes beneath modern shop fittings. This structure is an exemplary representation of medieval and post-medieval vernacular commercial and domestic architecture once prevalent in York.

Figure 1. 60 Goodramgate, York. Left: Property in May 2023. Right: Front and back elevations (© 2020 Maybank Buildings Conservation, adapted with permission).

Figure 2. Aerial view of 60 Goodramgate with the tile (left) and slate (right) roofing systems.

The site is also significant due to its relationship to Lady Row, believed to be the oldest row of houses in York. Our Lady Row is renowned as "one of the most celebrated of all surviving early rows of single-cell houses" (Grenville, 1997). It is plausible that, like other parish church properties in the city, this row of tenements was originally constructed to provide financial support for the Holy Trinity Church. The initial construction dates back to 1316, featuring first-floor 'jettying' that overhangs the ground floor (RCHME, 1981).

This study builds upon the recent exterior restoration work, specifically the lime rendering, as shown in Figure 1. The data presented here comprises approximately one year of research, aimed at informing further decisions regarding building adaptations.

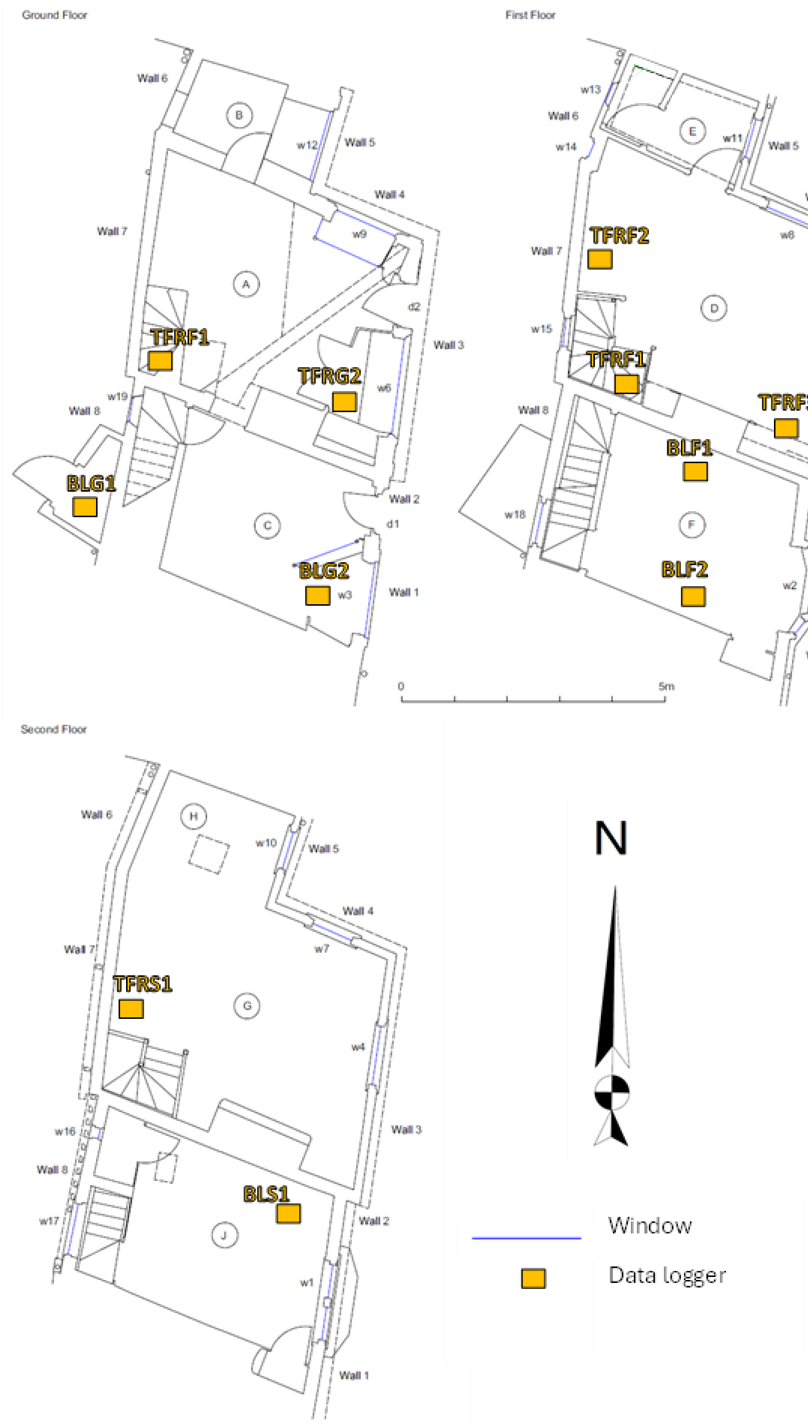

Figure 3. Floor plans of 60 Goodramgate. Location of data loggers noted in yellow, with the either timber framed (TF) or the brick (B) structure, and floor level noted in the logger coding (© 2020 Maybank Buildings Conservation, adapted with permission).

As the right and left side of the building are of different construction materials, a comparative method has been adopted to analyse the thermal and humidity performance of the timber framed structure (right) versus the brick structure (left). For this purpose, the loggers of each floor level have been grouped together, and then the data from the brick structure left-hand loggers (BLF) of that floor have been compared with that of the timber framed right-hand loggers (TFRG) the floor level is the final letter of the code. Using this categorisation, the performance of different floor levels has also been compared to each other to identify certain patterns. Overall performance of each logger, grouped by room, is provided in Table 1 to aid analysis of each room and the structure's overall performance. Given the large data set of the project, the minimum and maximum outdoor temperatures of selected dates are compared to the minimum and maximum indoor temperatures. Data from days with extreme weather conditions have been selected to represent the performance of each room and the building as a whole. If thermal performance is adequate in the warmest and coldest conditions, it can be inferred that it will also be adequate in intermediate conditions. The selected days include the warmest days of each summer month, namely: 25/06/2023, 07/08/2023, and 09/09/2023. The coldest day of each winter month has also been selected: 02/12/2023, 17/01/2024, and 25/02/2024. These dates were further verified with external weather data from the local weather station approximately 1.7 miles from the property. Given the relation between humidity and temperature, the selected days are also some of the least and most humid days, representing interesting points for data analysis. This data is then used to calculate the daily thermal inertia by decrement factor, for the purposes of this study a simplified calculation of the study carried out by Asan and Sancaktar (1998) was used. Total daily thermal inertia is calculated max. daily temperature (x) minus min. daily temperature (y)*: thermal/humidity buffer (%)= (x-y)/x * 100*. The higher the percentage of decrement factor, the more effective the building material is at creating a stable environmental conditions in the room. Thermal inertia or how slowly the temperature of a building reaches that of its surroundings, is influenced by the materials and type of structure used in the architecture, the presence and use of adjoining structures, solar gain, windows, and ventilation.

Table 1. Temperature, humidity and buffer values for each sensor, grouped by room.

Room	Logger Code	Min. temp.	Max. temp.	Min. Humidity	Max. Humidity	Avg. Thermal buffer		Avg. Humidity buffer	
						Winter	Summer	Winter	Summer
Ground floor right	TFRG2	1.7°C	24.7°C	52%	90%	86%	83%	78%	81%
Ground floor left	BLG1	2.2°C	22.2°C	58%	90%	87%	91%	80%	93%
	BLG2	2.7°C	21.9°C	57%	89%	88%	92%	78%	90%
First floor right	TFRF1	0.9°C	24.3°C	45%	100%	87%	87%	79%	87%
	TFRF2	0.1°C	25.1°C	44%	95%	84%	83%	80%	86%
First floor left	BLF1	2.3°C	30.5°C	44%	90%	78%	77%	68%	82%
	BLF2	2.4°C	25.5°C	52%	88%	88%	86%	80%	90%
Second floor right	TFRS1	-0.1°C	26.6°C	46%	95%	85%	81%	77%	86%
Second floor left	BLS1	2.0°C	26.2°C	51%	92%	83%	84%	80%	93%

4.1 *Limitations*

When comparing left and right sides of the building, there are several factors which affect the temperature and humidity of each of the buildings differently and make it impossible to attribute the variation solely to building materials. These factors include the area and orientation of external walls, quantity and location of windows, and volume of rooms. For instance, the room on the left brick side of the ground floor shares a wall with a beauty salon; it has fewer windows and is of a smaller internal volume than its right timber framed counterpart. Further to this the salon and shop on either side of 60 Goodramgate will impact winter readings as these structures are warmer due to occupation and use, the use of the upper rooms of these adjoining buildings is unknown, but again may be influencing the data. Notably, the rear of the building lacks windows and the building's chimney stacks have been removed and tiled over, limiting air movement in the building. The current disuse of the building will present a useful but not authentic reflection of issues which may be present when the building is in use. Therefore, it is impossible to attribute its superior thermal/humidity buffer and slightly warmer winter temperature to building materials alone. However, these factors still impact how much intervention each room may require.

The positioning of the loggers within a space highly influences some of the collected data and, therefore, does not completely accurately reflect the ambient conditions of the room in question. For example, BLF1 is positioned near a bay window and receives direct sunlight on sunny days, consequently recording very high temperatures and low humidity (Figure 4). These outsized highs and lows are not present in BLF2, indicating that BLF1 does not accurately reflect the ambient temperature and humidity of the room. Similarly, the left ground floor window has a much more opaque covering than that of the right, meaning that the BLG2 received less sunlight than TFRG2. Logger accuracy can also influence the perceived significance of the outcomes of the data, so consideration is needed when reflecting on the outcomes. While the wider research of this project included the attic and underfloor space of the structure, these are excluded from this publication for clarity of discussion.

Figure 4. Location of logger BLF1 (left) and logger BLF2 (right).

5. RESULTS AND DISCUSSION

5.1 Thermal Performance

Figure 5 shows the environmental conditions in winter and summer weather, indicating that the right and left structures perform similarly in both conditions. In summer months, the left brick structure performed slightly better than the right timber framed, though not to a highly significant degree in relation to overall human comfort. This variation was most evident on the ground floor, where TFRG2 showed about 9% more thermal buffering than BLG1 and BLG2. There was less disparity in the thermal buffer of the first and second floors, as the left structure provided approximately 2% more thermal buffering than the corresponding loggers on the right side of the building. TFRL1 and BLL1 show a thermal buffer of 17% and 38% respectively. In winter weather, the left structure still performed marginally better, but the thermal buffers of the right brick and left timber frame structures were mostly within 1-4% of each other. Exceptions include BLF1, which showed an average thermal buffer of 77%, notably lower than the nearby loggers – this is likely caused by direct sunlight from the bay window impacting logger readings at certain times of day leading to wider fluctuations and variability in the data.

In the summer months, unsurprisingly the upper floors generally recorded higher temperatures compared to lower floors. Whilst the outdoor temperature rose by more than 15°C throughout the afternoons, the indoor temperatures remained relatively unchanged within each of the main floor levels, fluctuating by only 1-2°C. The recordings were generally 4°C within each other, and the left structure was typically warmer than the right on the first and second floors. In winter conditions, the floor levels closest to the ground were warmer, but the indoor temperatures dropped to between 0-14°C.

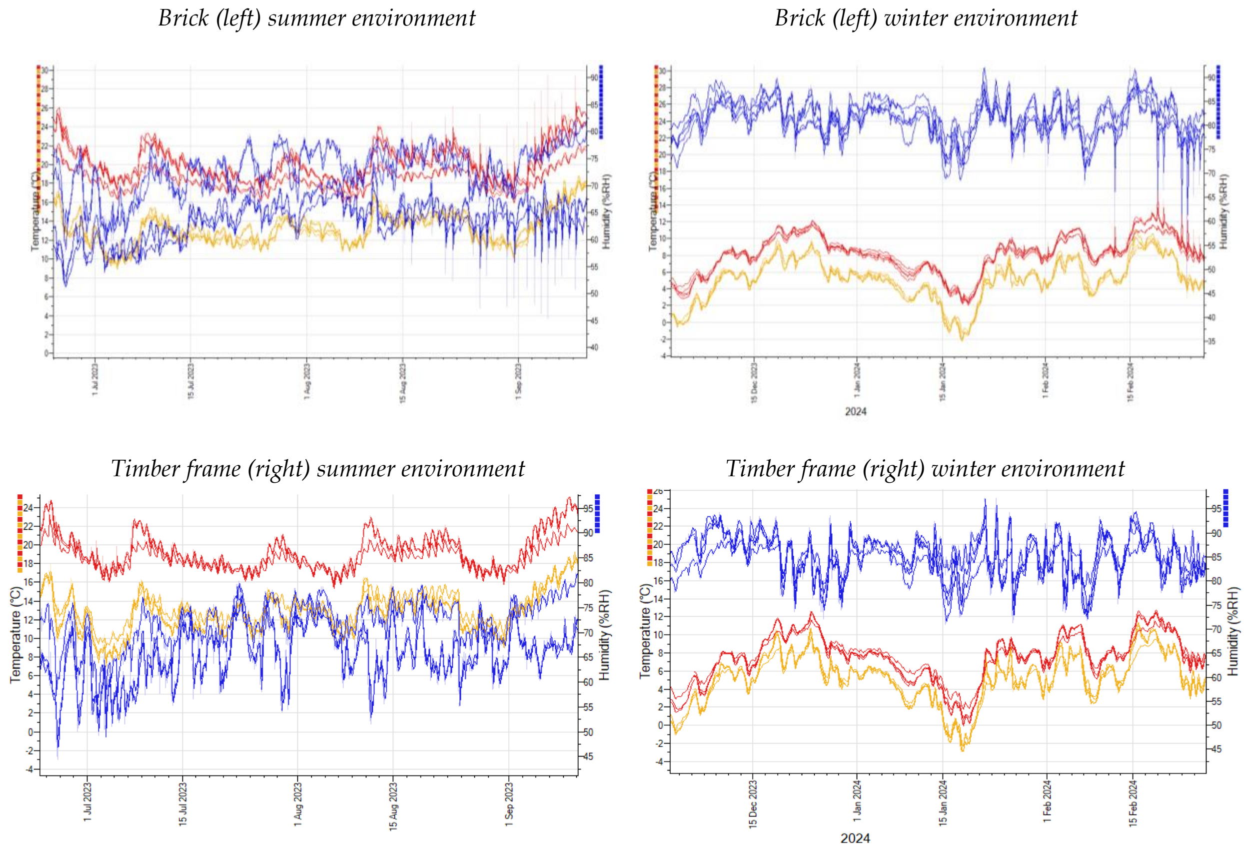

Figure 5. Environmental data graphs during the relevant study periods. Humidity noted in blue, temperature in red, and dewpoint in yellow. Note different scales are used for each graph for clarity.

5.2 *Humidity Performance*

In summer weather conditions, the RH level of the upper floors generally ran lower than the floors below. Despite the average 50% variation in outdoor RH levels on selected warm days, the indoor conditions stayed relatively consistent. On the ground floor, the left brick and right timber framed structures had similar RH levels with less than a 5% difference in their humidity readings. However, there were sudden drops in humidity readings of TFRG2, which was not evident in the left structure. On the first floor, the RH was consistently lower than the ground floor, and the difference in RH levels between the two structures occasionally reached 10%, with the right structure being more humid at most times. This pattern was followed on the second floor, although with a slightly lower RH.

According to the average humidity buffer presented in Table 1, the right timber frame and left brick structures are less consistent in their humidity performance than in their thermal performance, with the left brick structure generally showing better humidity buffering. In summer months, the left brick structure performed notably better than the right timber frame. On the ground floor, there was around a 10% difference in the humidity buffer of the left brick and timber frame structures, whereas on the first floor, the left brick structure provided only a slightly better buffering of 2%. The humidity buffering gap between the structures rises to approximately 6% on the second floor, with BLS1 showing 93% compared to TFRS1's 86%. In winter weather, the building generally provided less humidity buffering compared to warmer conditions but performed more consistently, with only 1-3% difference between the humidity buffer of the main floors of the left and right structures. BLF1, however, was an exception with a 68% humidity buffer, more than 10% below the other first-floor loggers.

As the outdoor conditions become wetter and more humid in colder winter months, there is less variation in outdoor relative humidity levels. The indoor humidity remains relatively stable, but in contrast to warmer summer conditions, the relative humidity is generally higher in the upper floors. The relative humidity readings of the ground to second floors are within 5% of each other, with the right structure being more humid than the left on each level. Though it is worth noting that given the level of accuracy of humidity the loggers record, this difference is negligible.

5.3 *Overall Assessment*

A primary concern with the environmental conditions reflected in the collected data is the persistent high humidity throughout the building as a whole for much of the year. This may seem counterintuitive considering that both buildings display reasonably good humidity buffers, however it is not surprising given the extended period of disuse in which the building has been unheated and unventilated. Consequently, the building's humidity levels have been allowed to incrementally increase and accumulate to unsafe levels. If the humidity levels are successfully reduced, the building's humidity buffer should be adequate to prevent them reaching unsafe levels again (assuming ongoing ventilation and heating). Therefore, providing ventilation will be the most crucial intervention, although it may be challenging given the imbalance of windows and lack of chimneys. Traditionally, fireplaces and chimneys help to ventilate buildings through convection, so a lack of chimneys will limit air movement throughout the building. Improving air circulation throughout the building should be a priority.

Thermal performance is a minor concern, as the building maintains reasonable temperatures across different weather conditions. However, performance in warm conditions could be enhanced by installing blinds on the large east-facing windows on the first and second floors, where direct sunlight likely contributes to occasional temperatures above 25°C. As the loggers do not exceed the 30°C threshold stipulated by Rupp et al. (2015) unless positioned in direct sunlight for extended periods, this suggests that extensive heat management is not a high priority. In winter, internal temperatures often fall below the 16°C minimum specified by the government, indicating a need for heating. Once a comfortable temperature is reached, the building's stable thermal performance should help maintain this with only moderate ongoing heating.

Materials like brick and stone, which have high thermal inertia, help stabilise indoor temperatures, keeping interiors cooler in warm climates and warmer for longer in cold climates. In colder regions, low thermal inertia materials like wood are often used, allowing spaces to heat up faster when it's cold. Heating and ventilation would also help dry the building materials, like brick and plaster, which perform better thermally when dry (Walker and Pavia, 2018). Both the timber and brick structures perform similarly, allowing for a consistent approach to environmental modifications throughout the building. This could include minimally invasive strategies such as installing a heating system and adding insulation with items like rugs and curtains.

The difference in minimum temperature between TFRF2 and TFRF3 (0.1°C and 0.6°C respectively) may indicate slight temperature variation between the buildings' east/front and west/rear sides, but not to the extent it would influence user experience. Some additional data could illuminate this effect in other parts of the building as one room is not enough to determine whether this difference is present throughout the building, but the general lack of windows on the west side of the building could plausibly cause such an effect. If confirmed through further investigation, this temperature variation within rooms could help determine the location of heaters. Additionally, positioning heaters at the rear of the building may help air movement via the staircases.

6. CONCLUSION

In summary, 60 Goodramgate currently exhibits good thermal performance with reasonable opportunities for improved humidity performance. Long-term disuse and consequent lack of ventilation have caused accumulative high humidity levels throughout the building, rectification of which can be prioritised through improved ventilation and strategic placement of heat. Once the humidity issue is rectified, the building's reasonably good humidity buffer should ensure it remains within safe humidity levels with ongoing ventilation and heating. The building's thermal performance is encouragingly good; air conditioning will not be necessary in warm weather, and in cold weather, moderate heating should be enough to maintain a comfortable temperature. The building's impressive thermal buffer indicates that extensive retrofitted internal insulation will not be necessary. Rather, unobtrusive interventions, such as curtains, blinds, or rugs, should be sufficient. The findings of this research have been used to support the YCT's decision making regarding the need for further interventive work at the property. The full report of the findings of this research project was used to support the program of works needed for the final phase of the development needed to transform the interiors into viable commercial spaces in the Listed Building Consent application.

This research highlights the principles of minimal intervention and the importance of understanding old buildings in heritage conservation. The study identifies that the building already exhibits good thermal performance, reducing the need for extensive retrofitting or intrusive upgrades. Understanding the building's existing strengths, such as its natural thermal and humidity buffers, ensures that any necessary interventions are as non-invasive as possible. By focusing on the building's inherent performance and working with its existing design, this research emphasizes the value of historical building knowledge. This approach preserves the building's historical integrity while making it more comfortable and sustainable for future use. Our research demonstrated the importance of creating preliminary information for the creation of minimal, well-informed and sustainable interventions in conservation practices.

ACKNOWLEDGEMENTS

We would like to acknowledge the support of our research partners, as well as the invaluable contributions from heritage conservation experts and sustainability advisors. Their work has been instrumental in shaping this study on sustainable practices in the historic environment. Special thanks to, Guy Bowyer and the York Conservation Trust for their collaboration on this project.

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