Practical challenges in mitigating the aftermath of fire in historic buildings

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Abstract

Fire is an unfortunate constant in the historic built environment which can cause rapid and potentially widespread damage to a building. Where buildings are of heritage importance there is normally a desire to reconstruct following a serious fire. In order to facilitate the possibility of this, what happens in the immediate post-fire period, as well as in the months that follow, can be critical. This article examines the challenges that are presented post-fire, when it may be necessary to respond to an urgent requirement to stabilise the building and protect it from further damage, before considering mitigation of subsequent issues including contamination and salvage. It goes on to consider a number of allied concerns that may also be of relevance soon after a fire, and are important in moving towards reconstruction. It is concluded that given the likely complex nature of the post-fire state it is important to plan for the possibility of such an eventuality and the necessity of providing an adequate organisational response regarding stabilisation, protection and mitigation. Additionally, the importance of having an adequate level of insurance cover is highlighted, since many of the processes discussed are costly, even before the main costs of reconstructing are incurred.

Key words: fire, post-fire, historic buildings, emergency planning, stability, archaeological salvage, reconstruction, documentation.

Figure 1. The interior of the Mackintosh Building at Glasgow School of Art following the 2018 fire. Note the distorted steel beams in the foreground; the hanging debris above and the badly damaged stonework on the left. The intense heat of the fire consumed the majority of interior fixings and finishes, leaving the brickwork exposed in most locations.

Introduction

Fire is amongst the swiftest and most destructive agencies that can impact on a historic building and is of significant concern because heritage buildings and the artefacts they contain are a precious and finite resource, and because fires continue to occur with unfortunate frequency. Data collected for England for example show that around 850 fires occurred in heritage buildings in 2019; of which over 80 caused serious damage to the building.[1] Fire consequently should be regarded as a distinct possibility for historic buildings, and therefore one that must not be ignored by those responsible for their care.

A recent article by the current author discussed the range of possible remedial interventions for a historic building that has suffered significant fire damage in order to secure its future; these being assessed from the viewpoint of conservation philosophy.[2] This article builds on this post-fire picture by exploring important additional elements: firstly considering the more immediate practical post-fire challenges; before going on to examine the related concerns and opportunities that are likely to inform and facilitate subsequent reconstruction (if this is in fact the appropriate option).

The time frame that this article deals with starts with the end of the immediate emergency response, which more or less equates with the handback of the building by the fire service (who will have assumed control of it until satisfied that the fire is out). However, in practice there may be some overlap, when the handback is not immediate, but decisions nevertheless need to be taken.

Only very brief details of the fires discussed are given here and the reader is referred to the previous article for further details.[3] The assumption is again made here that there has been a serious fire and that significant damage has been caused, or in other words that the scope of required intervention lies beyond that which would be covered by limited and localised repair.

'Razed to the ground' is very rarely the outcome for a historic building even after a serious fire, and furthermore a fire may only impact on a limited part of a much larger building, as was the case in both the Hampton Court Palace[4] and Windsor Castle[5] fires. There is thus often the opportunity for reconstruction if this is desired, affordable and appropriate from a conservation perspective. However to arrive at the point where reconstruction of a building is complete and it is ready to resume its former (or perhaps a new) function is likely to be a long and complex process. Actions to make this final outcome a possibility need to begin at a very early stage.

Many of the processes described below are costly due to the high level of specialist intervention and concomitant time input required, and therefore it is vitally important that these can be properly funded. Following the 2019 fire at Notre Dame Cathedral in Paris[6] initial work to temporarily stabilise the structure, recover stone and timber, and remove debris from the nave has cost around € 50 million.[7] This sum is affordable in this case (even though the cathedral wasn't insured for fire) because € 922 million has been pledged for its reconstruction.[8]

Although every fire is unique, there are commonalities in the challenges and requirements after all destructive fires in historic buildings, and these are explored here. The article is based on a multi-mode investigation of the aftermath of a number of key fires in historic buildings, which comprised an interrogation of the published literature and visits to most of the buildings discussed to obtain contextual data relating to spatial layout and fire spread, and to investigate current fire damage or subsequent reconstruction as apposite. The author also observed the Historic England 'Salvage and Disaster Recovery' residential course, which contributed further insight. Additionally a range of semi-structured interviews (10 in total) were conducted with key stakeholders and contributors involved both with specific fires and with planning for the possibility of fire in heritage and its aftermath. The aim has been to examine the key issues in the post-fire scenario and seek to identify, with evaluation in the context of actual fires, the main practical challenges that must be mitigated to facilitate future interventions.

The focus here is on important buildings which represent a degree of heritage significance that would be likely to imply that, even after a serious fire, efforts would be made to 'resuscitate' the building via the process of reconstruction.[9] For such buildings, what happens in the aftermath of a fire, and which is discussed here, is therefore of clear importance.

Practical challenges: the first response

When reconstruction is accepted as a likely option for the building, or to allow for the possibility of reconstruction where the viability of this is as yet unclear, the immediate concerns post-fire are making the building structurally secure and protecting it from the weather; followed by post-fire (archaeological) salvage and control of damp.

Potentially starting even before the fire service is able to give control of the building back to the person or organisation responsible for it, the immediate post-fire situation is likely to be logistically and practically complex with a range of stakeholders involved. Consequently

there is a need for coordination and leadership from the responsible person or organisation in what may initially be a dynamic environment.[10]

The post-fire scenario

The potential scenario following a serious fire is a weakened structure, possibly with important structural elements missing or compromised. This is not limited to timber elements; high temperatures will often also cause distortions to steel elements and damage to masonry. In some circumstances there may be the danger of large-scale collapse and even if this is not the case sections of the building, particularly at high level, may pose a risk. The building may also be open to the sky, since it is common for roofs to be lost in fires. Internal floors may have been partially or totally lost and ground floor rooms may be full of substantial amounts of debris from above. Basements may be full of water from firefighting operations.

Contained within debris there may be historically important material: artefacts which were in the rooms and not able to be salvaged during the fire, as well as important survivals from the fabric of the room itself (fragments of decorated ceilings; wall coverings, and so on). For the interior in general, it is worth bearing in mind that the level and nature of damage varies considerably depending on the combination of the individual building and the development of the fire; from complete 'gutting of the building', as occurred at the Mackintosh Building at Glasgow School of Art[11], to less extensive damage, as at Uppark[12], where despite the collapse of the roof and upper floors, at ground floor level much of the decorative plasterwork and timber panelling, and the ornate marble fireplaces, were either undamaged or only partially damaged.[13]

It is worth remembering that after any serious fire where the cause of the fire is unexplained there may be the need for forensic fire investigation to be carried out by the fire service. This may also be at the instigation of the loss adjustor. If this is the case, such an investigation may dictate that some the actions which are discussed below are delayed. At the time of writing for example, not all of the debris has been removed from the Mackintosh Building following the 2018 fire due to ongoing fire investigation requirements, since the cause of the fire remains as yet unknown.

Organisational response and decision-making

Some organisations, for example Historic Royal Palaces[14] in the UK, have looked specifically at the post-fire challenges and planned carefully for these, and following table-top exercises

to assess practical requirements, it has been recognised that having the key stakeholders, both internal and external, able to meet and agree on the course of action to be taken is important in the immediate post-fire situation, particularly given the need for urgent decisions to be made in some cases.[15]

The establishment of an internal team to facilitate decision-making may be required, though it is acknowledged that there is a wide range of possible types of property and of ownership or management. This range is perhaps bookended by, for example, a small privately-owned country house at one extreme and an extensive property which is part of a much bigger portfolio and owned or managed by a national organisation at the other. The internal decision-making process is perhaps relatively straightforward in the first case, increasing in complexity towards the other - where there may be the need for complex consultations before any decisions can be taken. Such decisions, to arrive at next steps which are realistically achievable, will rely on expert advice and will need to take into account the present condition of the building; the statutory framework for any immediate action and the necessity of having the ability to fund these actions. In some cases the required expertise may be available in-house, and in others it will need to be sought externally. For cases other than a singly-owned private building, and although in a large organisation longer-term decisions about the future of a building may be taken by a committee rather than by an individual, in the immediate post-fire period where urgent action may be required, it is important that a representative of the building or organisation in question should be in a position to make executive decisions.

Input may be required from a person (for example a building manager or surveyor) who has a detailed level of knowledge about the building - its fabric, layout and areas of particular significance; as well as potentially from conservators concerned with what has been removed from the building, as well as what may still remain within it. Depending on the nature of damage, advice may be required from a structural engineer, preferably with specific knowledge about the building, but as a minimum a specialist in historic buildings and accredited through an officially recognised scheme, such as the Conservation Accreditation Register for Engineers in the UK.[16] Allied to this, the involvement of scaffolding and demolition contractors may be required, the latter for removal of dangerous elements of the superstructure.

There will need to be representation of the local planning authority and potentially the relevant national authority (or body) charged with the protection of the historic environment. The former in England for example would be preferably a conservation officer where this

role exists (not all local authorities still have a conservation officer following widespread cuts in local authority budgets).[17] Additionally the national body, Historic England, is a statutory consultee for works to buildings which are scheduled monuments or are in the top two listing categories[18]. It is suggested that in all cases early consultation with such bodies is a necessity in order to avoid the possibility of breaking the law by carrying out unauthorised works, which could potentially lead to prosecution. The insurer also needs to be closely involved; normally a senior claims manager and a loss adjuster acting for the insurer, in order to give the insurer's agreement for any actions proposed.

Stability and temporary protection

Following a well-developed fire it will be necessary to assess whether or not structural stability has been compromised and there may be the need for urgent action in an initial making-safe phase to protect the public (depending on location) and to protect those working in and around the building. Assessment may be required during the fire itself, as happened for example during the fire at Clandon Park in 2015[19] when there was concern about cracking that had developed.[20] Once the fire is out, more detailed inspection and assessment may be required as a priority and potentially complicated by the difficulty of access, particularly to high level. This was facilitated by crane and the use of a drone at Clandon Park[21]; and by crane and mobile elevating work platform in 2018 at the Mackintosh Building, with the structural engineer able to carry out a comprehensive inspection of the building within days of the fire.[22]

After the 2018 fire at the Mackintosh Building adjoining streets had to be closed and residents evacuated because of uncertainties about the stability of the building. This contributed to an already difficult local situation at a time when there was a possibility that the building would be demolished. The early intervention of a structural engineer with very detailed knowledge of the building helped to avoid this eventuality. However, it should be remembered that the current condition of this building remains very fragile, and it is held in position with the use of an extensive support and restraint system; the placing of this means that certain streets have had to remain closed or partially obstructed.

For Notre Dame Cathedral, following the 2019 fire, the structural condition of the building has been of primary concern and initially it was feared that widespread collapse might occur; on the first anniversary of the fire in April 2020 the cathedral was still considered formally at risk.[23] The situation is complicated by the lack of a roof, damage to the stone vaulted ceiling (partially collapsed) and hundreds of tons of unstable and badly fire-damaged scaffolding,

which was in place as part of renovation work before the fire. Initial work has been carried out to stabilise the building, most notably by reinforcing the flying buttresses with timber supports (225 tons of timber were required to support the 28 flying buttresses).[24] At the time of writing the next stage in this process - the delicate operation to remove the scaffolding without triggering its collapse - which was delayed due to the COVID 19 pandemic - has now begun.[25]

Although the preference is to disturb as little as possible, where fire debris is actually in the way of installing internal structural support to the building there is a potential conflict between the need to provide such support quickly on the one hand and the need to sort through debris slowly and methodically (discussed below) on the other. It is suggested that, in this situation, installing the necessary support will take precedence, since the alternative could be far more onerous for the future of the building than the loss of a limited amount of evidential material.

It is worth noting here that in any country the statutory authority may have legal duties and powers in the interests of public safety related to a structure that has become unsafe as the result of a fire. In England and Wales for example the local authority, via its building control function, can require part or all of a dangerous building to be demolished where there is the need to act swiftly to remove the danger presented.[26] This is obviously a concern for historic buildings, given that in such a case any legal protection the building may have as a result of being of historic importance doesn't apply and, whilst the building control teams will work closely with stakeholders to look to retain any structure, where this is impossible demolition or partial demolition may be unavoidable.[27]

Even when the main structure of the building has been deemed to be safe, there may be challenges within the building before safe access for the purposes of recovering the contents can be allowed. Where floors and ceilings have collapsed hanging debris has frequently been an issue. At Clandon for example large beams were left hanging after the fire and fireplaces were hanging from the walls of upper floors. These had to be removed by crane and restrained in position respectively because of the danger to people who would be working below.[28]

There is also a need to safeguard what remains after the fire from the weather for the purposes of protecting the building structure; archaeological salvage, and recording and understanding the precise form of construction (which may have been hidden from view

despite possibly good documentation of the building). Analysis of what remains, as well as its condition, may have a decisive impact on future plans for the building, and establishing protection is particularly urgent where the roof has been lost in the fire and the tops of the walls, as well as the interior of the building are exposed. With the building fabric potentially already very wet if any quantity of firefighting water has been used, a further concern following fire damage should be to ensure that no further water enters the building.[29]

Protection is usually provided by scaffolding the building, which often includes some form of side-cladding and a temporary roof for weatherproofing. This can also provide for stability for the remaining structure and may incorporate additional structural support, for example horizontal lattice beams were used to provide restraint after the fire at Hampton Court Palace[30] and are currently being similarly used in the Mackintosh building. All temporary structures should be well-designed and robust; two workmen were tragically killed at Uppark when the temporary roof blew off in a storm; this also exposed the building to the weather for a further 6 months before a replacement was installed and the interior suffered further damage.[31] Since the process of investigation, assessment and possible reconstruction will in all probability be over an extended time period, the design of such structures must, in addition to taking into account a full range of seasonal conditions, use materials which offer suitable longevity. It is notable that although it is common practice to rent scaffolding, including temporary protection such as side-cladding and roofs, because of the lengthy period likely to be involved in the reconstruction of historic buildings, in some situations the more cost-effective response has been to buy the scaffolding. This was done following the fire at Hampton Court, and was also done, on the insurer's insistence, at Clandon Park.[32]

Although on occasions temporary protection has been installed very quickly, for example above the King's Apartments at Hampton Court Palace where the temporary roof was in place after just 18 days[33], the potential lengthy period required to source and erect temporary protection should not be underestimated, and in a number of cases months have passed before weather tightness could be achieved. Given the high annual rainfall in the British Isles and the recent increases in periods of exceptionally high rainfall, the amount of water falling onto an exposed building is potentially more of a problem than that caused by firefighting water (Ridout gives the example of a building where 159,000 litres of water were used to fight the fire, but an estimated 193,400 litres fell on the building as rainfall in the 6 months before it was fully protected).[34] There is the added complication that weather protection once installed may well make the drying out process slower by reducing through-ventilation.

All of the above operations require specialist advice and works, and the insurer should be consulted throughout the process to ensure that they accept the proposals. Some organisations may have well-established contacts for specialists and in other cases it may be the insurer who sources and appoints directly.

Practical challenges: the next steps

The health and safety concerns discussed above must be addressed before it is be possible to gain access to the building and commence with the next steps described below. Ideally, where possible, these concerns should be mitigated in a timely fashion, since important artefacts may be capable of being rescued and conserved if this can happen before further, largely damp related, deterioration takes place. Unfortunately however, immediate access can be problematic for a variety of reasons; at Clandon Park it was 6 months before it was possible to get into the building for conservation purposes and even though at that point a temporary roof had not been completed it was felt that further delay to wait for this would be likely to cause further deterioration in the interim.[35]

Contamination

The use of lead, particularly in roof coverings, is widespread in historic buildings and represents a potentially serious problem of contamination if a fire has been serious enough to involve the roof and cause consequent melting of lead, as has occurred in a number of cases.

At Clandon Park, following initial testing, it was known that the debris in the building was heavily contaminated with lead, and plans for how the site was to be managed and how materials removed from the building were to be dealt with had to be developed. Subsequently persons working with the material were protected with specialist Personal Protective Equipment (PPE) and were given regular blood tests. Anything of heritage value that was subsequently removed from the building, including items from the house collection, sometimes in small pieces, as well as historic fabric from the building itself (such as plaster fragments from the decorative ceilings), had to be decontaminated - a laborious and expensive process.[36] In addition to this, once sifted for anything of value, the contaminated debris also had to be removed and disposed of; this is expensive as it has to be carried out by specialist contractors since the waste is classified as hazardous.[37]

Notre Dame reportedly had 400 tons of lead on the roof and spire[38] and contamination is a significant problem. The lead levels close to Notre Dame after the fire were described as 'astronomical', more than a thousand times the acceptable limit, and the French Culture

Ministry was strongly criticised for being slow to react and putting at risk the health of local residents as well as workers at the site itself.[39] At one point the site had to be closed because of this.[40] Strict and extensive control measures to protect workers on the site are now in place however, with the use of check procedures and full PPE.[41]

There are further potential causes of contamination in historic buildings post-fire, not least that caused by the presence of asbestos containing materials. These may have been either unknown or managed in situ prior to the fire, but could be widely distributed as a result of damage or collapse caused by the fire. Specialist input and advice will doubtlessly be required to deal with such contamination.

In all cases where there is contamination, the result is likely to be slowing down of a conservation response, increased costs and more onerous working conditions for those involved on site.

Archaeological salvage

After a serious fire it is common to see interior ground floors - or basement spaces if the ground floor has been destroyed by the fire - filled with quantities of charred debris from several storeys of collapsed structures above: such as roofs, floors and ceilings. This is often very wet from firefighting water and can be several metres in depth. It is consequently complex and time-consuming to deal with; a job which has been described as long, exhausting and dirty.[42] It used to be common practice to simply remove this debris and dispose of it, and this is what happened for example following the fire at the National Trust property of Nostell Priory in West Yorkshire, in 1980[43] (this is a Grade I listed Palladian house, constructed in 1736-1750[44]; the damaged rooms were later reconstructed).

After the fire at Hampton Court Palace in 1986 a different approach was adopted, with a process described as 'total salvage' being adopted[45]: the material was carefully investigated, with recording being carried out. Besides the recovery of artefacts this was found to be very valuable for subsequent reconstruction, both in having an evidential basis from which to reconstruct lost work of which only fragments remained, with a concurrent reduction in conjecture, and also in maximising the reuse of original fabric; it was estimated that 75% of the oak panelling; 62% of the soft-wood panelling and 64% of the original mouldings were able to be reused.[46] This practice has subsequently become the norm and is usually referred to as archaeological salvage. In some cases a painstakingly detailed 'micro-sifting' of the material is required, such as was carried out at Hampton Court and Windsor Castle to ensure

that none of the individual pieces of the chandeliers, which had in both cases fallen with the ceilings, were lost.[47]

The floor areas of each room are commonly divided into a marked-out grid pattern, suspended above if not possible on the actual floor, in order to record exactly where material is removed from. This not a simple process, since material from several floors above may well be mixed in with that from the room in question. Following on from the work at Hampton Court, at Uppark a two-part process was used: anything identifiable was recorded and removed and the rest of the material was loaded into location-marked dustbins (which ended up being nearly 4,000 in number) for subsequent sifting[48]. 40,000 individual fragments of plaster were recorded[49] and were subsequently reused where possible in the reconstruction, particularly in the ceilings. A similar process was used at Windsor, where 8,400 bins were required along with the use of a conveyor belt to aid with the sorting of material. [50]

For contents (artefacts and collections) salvaged during a fire and which have become wet, or damaged in other ways, in the process, there is the need for early-stage on-site expertise to deal with items that are often financially and historically valuable. This should ideally incorporate an initial triage system to establish priority, assess damage and provide 'first aid'. This type of work is often the domain of specialist conservators, who may be experts in only one aspect - for example textile conservation or painting conservation. This function may well need to continue post-fire for an extended period as further contents are removed from the building. These might be items that were too heavy or difficult to move and may have been protected in situ[51], or that it wasn't feasible to salvage during the fire for a variety of other reasons. Although items might subsequently be sent elsewhere for more controlled specialist treatment, there is the urgent requirement for on-site facilities which at the very least will need to offer weather protection; it would be inexcusable to remove a valuable item from the building only for it to be damaged by the weather. There is also often the need for storage space for salvaged items and material, and this is increased where items need spacing out in order to assist with drying (such as for example recovered timber elements). Temporary storage, erected close to the building to reduce handling, has been adopted in most cases; often taking the form of temporary structures such as large and semi-permanent marquees or Portakabins. Allied site-office space and welfare facilities will be needed, and can be also provided with the use of Portakabins or similar.

Drying out

The use of firefighting water often in large quantities, to either extinguish or control fires, is likely to result in a very damp building, and in addition to items and material moved from the building as discussed above, the actual building fabric as remains in situ may also need considerable time to dry out - which is a necessity before repair work and the application of finishes can be carried out. Where fire damage is only partial, and there is therefore susceptible fabric remaining within the building, damp post-fire conditions increase the possibility of outbreaks of dry rot and other timber-destructive fungi, which can be highly damaging to historic fabric. Dry rot is particularly destructive, and is endemic but dormant in many historic buildings; after a fire the environmental conditions may unfortunately prove ideal for it to thrive.[52] Many species of fungus in fact favour conditions that are damp and lacking in ventilation, and in post-fire historic buildings there may often be an abundance of suitable concealed spaces, for example under floors, behind panelling and in void spaces. In some cases it has been possible to assess such areas by drilling holes and inspecting using fibre optic technology.[53] Subsequently, there may be the need to actually remove some elements of the building that have survived the fire in order to aid in the drying process. Accelerated drying techniques, such as by the controlled use of fans and dehumidifiers, may be also required to supplement any possible natural drying (by opening windows to increase ventilation for example).

At Windsor Castle an estimated 6.8 million litres of water had been used in fighting the fire, delivered at up to 18,000 litres a minute at the height of the operation, and had soaked into the very thick medieval walls and vaults; the building was later described by the senior project manager as being a "very, very wet castle".[54] In fact, 2 years later the brickwork below the Green Drawing Room was found to be still at 80% saturation (normal levels should be below 5% to be considered dry).[55]

The recommendation from the consultant tasked with addressing the damp issues was initially to avoid hurry in the drying-out process and to dry materials in situ where possible. Timber panelling for example would be less prone to warping during the drying-out process if it could dry out in situ. However there was the necessity to return the building to use within a very limited time period, the building was still very wet and the drying out in situ would have taken several years; the dampness of the building had become a major obstacle to allowing the reconstruction project to move forward. The key issue was that walls were not drying out and to facilitate this it would be necessary to remove plaster, cupboards, panelling

and so on. This though was problematic in a building where the historic fabric was protected and the normal approach would seek to minimise impact to that fabric. Lengthy consultation and negotiations with the national heritage authority[56] were therefore necessary before it was eventually agreed to remove surface finishes in some areas to allow for drying out. This was augmented with the use of extractor fans, dehumidifiers, open windows and use of the heating system. These measures didn't prove to be sufficient and later it was reluctantly decided that it was necessary to remove historic wall linings, including panelling, to further help with drying.[57]

Further concerns and opportunities in the post-fire period

Having considered the immediate challenges which arise in the aftermath of a serious fire, there are a number of allied concerns, some of which may begin in tandem with the above, with others more likely to occur later; all subsequently have a role in informing decisions about a building's future. Furthermore, initiatives related to building knowledge, improving documentation and the availability of materials although treated separately here are often interrelated and may typically occur simultaneously in practice. Although inevitably there can be substantial loss of historic fabric in a serious fire there are also a number of opportunities created, related to the subsequent reconstruction process, where this is the selected option. Even where such an option is not possible, there are nevertheless some opportunities for learning from the building.

Although it is not uncommon for a substantial period to elapse following a fire before any reconstruction work might commence, and this gives time for careful appraisal of longer term options and further challenges, in some cases there are strong drivers which result in a quicker resolution. Such was the case at Windsor Castle where there was a need to finish the work in as short a time as possible so that the important state function of the Castle could resume and the reconstruction project was finished within 5 years of the fire. Similarly, when there was a need to return to use an important component of an art school with over 2,000 students, work on the Mackintosh Building was nearly complete 4 years after the fire in 2014 (the position following the second fire is however far more complex). In other cases, there has been a much slower reaction. At the time of writing, work has not yet started at Clandon Park though 5 years have passed since the fire. Contrastingly in France, where work actually started very quickly at Notre Dame, there have been subsequent delays due to bad weather and COVID 19. As a result, the promise made by president Macron immediately after the fire for the reconstruction work to be completed within 5 years, already considered to be overly-

optimistic[58], may now be unachievable. In cases where there is urgency to return buildings to functional use it is more likely that the challenges already discussed and the concerns covered below may occur in parallel.

Building knowledge: previous forms; construction and use of materials

A serious fire exposes more of the underlying layers and structure of the building than would ever have been possible in the normal life of a building; this might be as a direct result of fire damage or because of removal of building fabric and surface linings to aid in drying-out. In some cases this may reveal previously unknown information about the building - in terms of changes to layout; construction form and materials. This is an important learning opportunity which can add significantly both to knowledge of the individual building, and more generally to knowledge of historic building practices, construction techniques and use of materials. Such revealed detail will require careful investigation and recording (see next section) and could influence reconstruction choices.

Many historic buildings have undergone changes during their lives and a fire can provide details of previous forms for the first time. A good example is provided by Uppark, where very little had been touched since the late 1700s. After the fire it was possible to work out the internal layout of the original house (dating from 1689); in particular exposure of the internal masonry structure made it possible to see the original position of doors, windows, fireplaces and room partitions. Previous assumptions about the house were found to have been wrong.[59] Similarly, the fire at Windsor Castle provided a wide range of new information about the building. What had been believed to be an almost entirely 19th century castle above ground level was found to contain medieval masonry, and evidence of a multitude of historic alterations was found. Hidden below the surface and revealed by the fire and subsequent work was what has been described as the material account of its own history.[60] The roof structure in the Great Kitchen, previously thought to have been a 19th century design, was revealed to be late medieval, dating from the 15th century, and it was further established that this was the original medieval royal kitchen, which documentary evidence identifies in existence in 1259, and had never been in another location (as had been previously thought).[61]

In other cases, specific details about the use of materials have been discovered. At Hampton Court Palace for example, when floorboards were removed post-fire to aid ventilation, it was discovered that thousands of seashells had been packed between the joists, thought to have been used in the 1600s to provide sound insulation for the King's rooms below.[62] These had actually slowed the rate of burning during the fire. Historic evidence was also revealed:

plaster surfaces exposed by the removal of timber panelling showed a range of previously unknown drawings, signatures, graffiti and handprints.[63]

The fire at Notre Dame has been recognised as a great opportunity for research to be undertaken on the building and this is important since the current picture is far from complete because of the great age of the building (construction was started in 1163 and there is little documentation about the building process).[64] Furthermore the fire has opened up access to parts of the building that could not be studied when the structure was intact.[65] Recognising the opportunity, the day after the fire the 'Association of Scientists in the Service of the Restoration of Notre Dame of Paris'[66] was formed, with the aims of coordinating the work of experts in various fields, sharing knowledge and supporting scientific study of the cathedral.[67] (There are currently around 250 members, representing a truly international cooperation in historic building research.) Within a wide range of aspirations, it is hoped for example that study of the remains of the timber used in the construction of the roof structure of the cathedral will shed light on where exactly the timber come from and how it was chosen, research that wouldn't have been possible without the destruction caused by the fire.[68]

Improving documentation about the building

Whilst having a high level of documentation for any important historic building is desirable in a normal situation, it becomes particularly relevant after a fire, especially where there is the need to avoid conjecture in any subsequent reconstruction and to facilitate accurate costing for this. Unfortunately however in reality it is often the occurrence of a fire in itself which exposes lack of documentation and provides the impetus for its improvement by detailed recording. Achieving a comprehensive level of documentation also provides the information that might be needed in the planning of future conservation interventions and adds to knowledge of historic buildings in general. In terms of the former, reconstruction work carried out after a fire will itself also need to be carefully documented.

The technology used to document buildings has evolved from the use of traditional hand-drawn plans and black and white photographs, to the point where geospatial datasets, such as point clouds (based on laser scanning), and data from photogrammetry, can be integrated into Computer Aided Design and Building Information Modelling software to produce highly detailed 3D digital models of historic buildings. It is important that digital data is future-proofed on an ongoing basis in order to continue to be readable as software and hardware evolves.

The first fire at the Mackintosh Building at Glasgow School of Art, which occurred in 2014, resulted in a surge of research into and documentation of the building. The decision was taken to do detailed digital modelling of the entire building, based on laser scanning and supplemented by site measurement and investigation.[69] This, in combination with archival research meant that by the time of the second fire in 2018, the Mackintosh Building had become one of the best understood and documented historic buildings in the world. It is only because of this that there exists the possibility of achieving a near-authentic reconstruction of the building following the 2018 fire.[70]

At Notre Dame, a highly detailed 3D-digital model of the cathedral is being created that is intended to show every stone and timber in the structure. Recorded in the model alongside the geometric data about the building structure will be detailed data about construction elements and materials from the scientific study of the cathedral, with the intention of producing a comprehensive and single source of information, available to guide the current and future interventions.[71]

Availability of materials

Since authenticity in terms of reconstruction after a fire is not vested in original historic fabric, since this may have lost, but in using the correct materials and techniques to replace this fabric where necessary, how authentic any reconstruction can be depends to a large extent on the availability of the original construction materials, as well as the skills to work these.

The first challenge is to establish exactly what has been lost. In some cases detailed records exist in a property's archives (for example invoices and bills of quantities) and the source and exact type of materials is obvious. If such records are lacking, it may be necessary to carry out some degree of forensic investigation on remaining fragments. This presupposes that something is left to investigate, is in any case far from ideal as it is expensive and time consuming, and serves to emphasise the importance of detailed documentation as a precautionary measure.

In addition to materials lost in the fire, it may prove necessary to assess the integrity of materials which may show little visual sign of damage, and in some cases scientific testing will be required. Stone in particular can be seriously affected by a fire and may be internally damaged both by the heat from the fire and by thermal shock caused by firefighting water. Stone replacement was required in the Mackintosh Building following the 2014 fire for this

reason, and damage is more widespread following the very high temperatures reached during the 2018 fire (firefighters described these as the highest they had ever encountered).[72] At Notre Dame it will also be necessary to determine which of the stone blocks can stay in place or be reused, and which must be replaced as a result of fire damage.[73]

Once the provenance of and exact requirements for materials is established it will be necessary to find out if replacements might be available, in sufficient quantity, either from the same or an alternative source. A good example of this is the timber that was required in the reconstruction of the Mackintosh Building library, for which the nearest match was found to be an American tulip wood and for which a supply proved to be available.[74] (It is understood that some of the painstakingly reconstructed timber elements for the library had fortunately not yet been installed in the building before the 2018 fire[75]). On occasion a near-equivalent material might have to be used where no exact match is available.

Ongoing production of traditional building materials helps ensure a continuing supply for future repair work[76], though it could be the case that a sudden demand for such materials after a large fire might be the catalyst to facilitate a restarting of production.

Traditional Skills and Training

Any work done to historic buildings should be carried out by skilled people who have gained conservation experience and expertise[77] and the requirement for the highly-skilled craftwork required to reconstruct following fire highlights the importance of the training of new craftspeople to provide sufficient work capacity. In fact, reconstructing in the original materials after fire, perhaps throughout the building, is a fantastic opportunity to boost the availability, level of knowledge and level of competency of those trades skilled in traditional construction methods and materials, which benefits not just post-fire reconstruction, but the wider heritage sector.

There is a common misconception that the ability to carry out fine-quality traditional work is dying out, but successfully completed projects in the UK and elsewhere have shown conclusively that there can be both the capacity and the level of skill required to carry out quite extensive post-fire reconstruction; a necessity for authentic reconstruction to be countenanced.[78] It should be noted however that, given the size of the building, following the Notre Dame fire questions have been raised as to whether there will be sufficient capacity of skilled and specialist craftspeople to carry out the work if an approach of authentic reconstruction is adopted, with estimates that 100 stonemasons, 150 carpenters and 200

roofers will be required.[79] Unfortunately, it is highly unlikely that Notre Dame will be the last significantly important historic building to suffer a catastrophic fire, and unless such skills are used and developed they will disappear, and our future potential to reconstruct such buildings in original materials will be compromised.

There may be opportunities to learn about techniques, or specific details of techniques, which may have been lost to time, in order to ensure the authenticity of any reconstruction work, and once these are understood, they can subsequently be used in future projects. Following the decision to adopt an approach of authentic reconstruction at Uppark, the replacement of five large decorative plaster ceilings, described as being of extremely elaborate design, was of key importance.[80] The original ceilings had been made using in situ free-hand modelling of lime and hair plaster, a technique that hadn't been used for more than 150 years. This had to be effectively rediscovered, for example the precise types of materials used and exactly how the fine detailed shapes were achieved, and a collaborative effort was required involving academics, scientists, artists and plasterers. Repetitive mouldings were made in workshops offsite, but the fine artistic work was carried out free hand and in situ. Persons identified as being potential candidates to work on the latter were required to provide samples of their work before being approved and this is a check that is quite common in selecting for fine-detailed reconstruction work. The whole process was complicated by the need to incorporate recovered pieces of the original ceilings, in their correct positions, into the new.[81] The end result is of impressively high quality, and the craftspeople involved have since been in demand to work on other projects. The reconstruction of the decorated ceiling in the Marble Hall at Clandon Park will doubtless benefit from the now well-established pool of expertise.

A further example, illustrating the fine level of detail that may require investigation, was the discovery that Grinling Gibbons' fine carving at Hampton Court, which was originally thought to have been left 'as it came from his chisel' had in fact been finished using some kind of abrasive technique.[82] For damaged sections of carving which required replacing it was desirable to reproduce this in order to have a matching finish to that of the original, and after experimenting with a number of possible solutions it was found that the use of a particular type of plant as a sanding agent produced exactly the same finish (this is uncommon in England but was being imported in large quantities from Holland at the time of the original carving).[83]

Services

With a significant level of damage to a building there is the opportunity in the process of reconstruction to improve the building for contemporary needs, if there are the financial means to allow for this. In building conservation terms this would be 'adaptation' as defined in the widely adopted Burra Charter.[84] It is very clear that this is only acceptable where it would have a minimal impact on the cultural significance.[85] The introduction of new services is common - for example modern electrical systems and modern fire detection and alarm systems - and such adaptations may be required to satisfy building codes or regulations (though these may be relaxed for historic buildings in certain cases). Such adaptation is an unavoidable addition to authentic reconstruction and it would make no sense to ignore this opportunity; it would in any case be impossible to install for example an electrical system exactly as it was 'the day before the fire'.

There may also be the chance to introduce systems which enhance the protection of historic fabric or contents. In the reconstruction of Uppark for example the new heating system was designed to maintain the relative humidity at an appropriate conservation level.[86]

Conclusion

Although the various post-fire considerations presented are discussed discretely here, it is as suggested likely that in reality several of them may be occurring simultaneously. This means that the post-fire situation is potentially very complex and quite difficult to manage, and consequently it is very important to have an organised response and the ability to make relatively quick decisions. Whilst it is obviously preferable to apply all possible measures to minimise the possibility of the outbreak of, spread of and damage from fire in historic buildings, and much has been achieved in this regard, there is nevertheless an unfortunately high incidence of such fires. It is therefore strongly suggested that rather than having a wholly reactive response after a fire it is necessary to actually plan for the eventuality of a post-fire situation in order that the required decisions and the related interventions discussed here can be carried out in the most effective and efficient way; not to do so risks wasting time and causing more damage - potentially jeopardising the building's likelihood of survival and at least the ability to efficiently reconstruct. Such planning is most suitably included as a part of overall emergency planning, which should consider responses both during and after a fire. Where the size of the organisation warrants it, all stakeholders should be called together for planning exercises, in which context priorities can be identified and any potential problems addressed and mitigated.

The dissemination of this message is important since although in some countries, including the UK, significant buildings are generally suitably protected against fire, and the importance of planning for an organised emergency response is frequently understood, in many other countries little has been done to either safeguard irreplaceable built heritage against fire or mitigate the impact should it occur.

The ongoing possibility of fire in historic buildings and a likely desire for subsequent reconstruction of important buildings, should this prove to be a reality, also offers a strong argument for making determined efforts to improve the recording of and documentation of all such buildings to make interventions more easily achievable and to reduce conjecture. Furthermore, despite the exceptions (notably Notre Dame) where sufficient funds are available from other sources, in most cases insurance is essential. It must also be of adequate level, since if reconstruction is the choice of intervention, both carrying this out in the longer term and making it a possibility, via the processes described here in the shorter term, will require substantial funding.

Fires have always been an interruption in an often long history of a building and will continue to occur. For important buildings they are not necessarily the end of the story and facilitating the rebirth of the building, partly by planning for the aftermath, should be part of the remit of those charged with their care, and should be included in an overall holistic approach to managing fire safety with the aim of safeguarding the finite asset that is built heritage.

Bibliography

Associated Press. *Notre Dame rector: Fragile cathedral might not be saved*. Published December 25, 2019. Accessed January 14, 2020. https://apnews.com/48fee6c01627bca5f212c0f2e35d81cf

Brown J. (Architect, Page\Park). *The Mackintosh Building in a post-fire context*. Interview with the author, March 13, 2019. Personal communication.

Australia ICOMOS (International Council on Monuments and Sites). *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance*, 2013. Accessed January 29, 2019. https://australia.icomos.org/wp-content/uploads/The-Burra-Charter-2013-Adopted-31.10.2013.pdf

BBC, *Rebuilding Notre Dame: Inside The Great Cathedral Rescue*. Documentary, broadcast on 15 April 2020.

Crowdy, T. (Fire and Emergency Planning Adviser, Historic Royal Palaces) *Post-fire interventions in historic buildings*. Interview with the author, April 10, 2019. Personal communication.

Daily Record, *Hero firefighters say Glasgow School of Art inferno was 'like fighting a volcano'*. Published June 25, 2018. Accessed May 6, 2020. https://www.dailyrecord.co.uk/news/scottish-news/hero-firemen-glasgow-school-art-12777164

Echlin D. (Structural Engineer, David Narro Associates). *The Mackintosh Building in a post-fire context*. Interview with the author, May 14, 2019. Personal communication.

Ewing D. (Head of Learning & Guidance, Local Authority Building Control). *Building control in a post-fire context*. Telephone interview with the author, May 12, 2020. Personal communication.

Fishlock, M. *The Great Fire at Hampton Court*. London: The Herbert Press, 1992.

Foy J. (Assistant Director, National Trust). *Clandon Park post-fire.* Interview with the author, April 10, 2019. Personal communication.

France 24. *A rare look at restoration of Paris's Notre-Dame Cathedral*. Published December 14, 2019. Accessed February 14, 2020. https://www.france24.com/en/20191214-reporters-granted-rare-look-restoration-paris-notre-dame-cathedral-fire-rebuild

France 24. *Delicate work of dismantling Notre-Dame's charred scaffolding begins*. Published June 8, 2020. Accessed June 8, 2020. https://www.france24.com/en/20200608-delicate-work-of-dismantling-notre-dame-cathedral-s-charred-metal-to-start

The Guardian. *Notre Dame cathedral sealed off for huge lead decontamination operation.* Published August 13, 2019. Accessed May 21, 2020. https://www.theguardian.com/world/2019/aug/13/notre-dame-fire-lead-contamination-clean-up-begins-around-cathedral

Historic England. *Listed Buildings*. 2020. Accessed January 28, 2020. https://historicengland.org.uk/listing/what-is-designation/listed-buildings/

Ministère de la Culture. *Notre-Dame de Paris : les enseignements à tirer d'une collecte sans precedent*. Accessed April 21, 2020. https://www.culture.gouv.fr/Actualites/Notre-Dame-de-Paris-les-enseignements-a-tirer-d-une-collecte-sans-precedent

Le Monde. *Y aura-t-il assez de compagnons du devoir pour rebâtir Notre-Dame de Paris?* Published April 17, 2019. Accessed January 13, 2020. https://www.lemonde.fr/les-decodeurs/article/2019/04/17/y-aura-t-il-assez- de-compagnons-du-devoir-pour-rebatir-notre-dame-de-paris_5451739_4355770.html

Murray C. (Preventive Conservation Adviser, National Trust). *Emergency planning for fire at the National Trust and the lessons from Clandon Park*. Interviews with the author, 16 March 2018; 29 May 2019 and 29 April 2020. Personal communication.

National Trust. *Uppark*. London: National Trust Enterprises Ltd, 1995.

New York Times. *Notre-Dame's Toxic Fallout.* Published September 14, 2019. Accessed January 13, 2020. https://www.nytimes.com/interactive/2019/09/14/world/europe/notre-dame-fire-lead.html

Nicolson A. *Restoration: The Rebuilding of Windsor Castle*. London: Michael Joseph Ltd, 1987.

Owen-Hughes S. (Chief Fire Officer, Surrey Fire and Rescue Service and Incident Commander at Clandon Park fire). *Fighting the fire at Clandon Park*. Interview with the author, May 26, 2017. Personal communication.

Ridout R. *Timber decay in buildings: The conservation approach to treatment*. London: E & FN Spon (Routledge), 2000.

Rowell, C., and J. M. Robinson. *Uppark Restored*. London: National Trust Enterprises Ltd, 1996.

Science News. *After the Notre Dame fire, scientists get a glimpse of the cathedral's origins.* Published January 18, 2020. Accessed January 22, 2020. https://www.sciencenews.org/article/after-notre-dame-fire-scientists-glimpse-cathedral-origins

Smithsonian Magazine. *Notre-Dame Restoration Delayed Due to Lead Poisoning Concerns*. Published August 13, 2019. Accessed May 29, 2020. https://www.smithsonianmag.com/smart-news/notre-dame-restoration-delayed-due-lead-poisoning-concerns-180972895/

SPAB. *THE SPAB APPROACH to the conservation and care of old buildings*, 2017. Accessed June 19, 2019.

https://www.spab.org.uk/sites/default/files/documents/MainSociety/Campaigning/SPAB%20Approach.pdf

Spring M. The Caretakers. *Building*, issue 39, 1991: 42-46.

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[1] Figures collated by Charlie Harris, National Fire Advisor Historic England, on behalf of Historic England, April 2020. These figures show an increase compared with the previous year.
[2] See Kincaid S. (2020), "After the Fire: Reconstruction following Destructive Fires in Historic Buildings", *The Historic Environment: Policy & Practice*, 11:1, 21-39.
[3] Ibid.
[4] Hampton Court Palace in England, a scheduled monument and Grade I listed (see note 9), has been a royal palace since 1529. The fire in March 1986 caused extensive damage to the King's Apartments in the Fountain Court area of the palace.
[5] Windsor Castle in England is a royal residence, occupied as such for over 800 years, and is a scheduled monument and Grade I listed. The fire in March 1992 caused severe damage to 115 rooms in the north-east section of the Castle, including major state rooms.
[6] Cathédrale Notre-Dame de Paris in France dates from the 13th century and is one of the most well-known buildings in the world. It forms an integral part of a UNESCO World Heritage Site. The fire in April 2019 caused extensive damage mostly at high level in the cathedral, impacting primarily on the roof and vaulted stone ceilings.
[7] France 24, *A rare look at restoration*.
[8] Ministère de la Culture, *Notre-Dame de Paris*.
[9] Important historic buildings are 'listed' in England to give them statutory protection: Grade I is the highest category, for buildings of 'exceptional interest' (2.5% of listed buildings are Grade I); Grade II* buildings are 'particularly important buildings of more than special interest' (5.8% of listed buildings are Grade II*) (Historic England *Listed Buildings*). A similar system is used in Wales; the equivalent in Scotland and Northern Ireland are Category A and B listings. The nationally most important building throughout the UK may have the additional protection afforded by being recognised as 'scheduled monuments'.
[10] Foy, pers. comm.
[11] The Mackintosh Building, finished in 1909, forms part of a Glasgow School of Art in Scotland and is Category A listed. The fire in June 2018 was the second serious fire to have occurred in the Mackintosh Building, the first having been in May 2014. The 2014 fire although very destructive was limited to the library, an external corridor and some studios and archival stores. Reconstruction was approaching completion at the time of the second fire which spread to the whole building, was highly destructive throughout and has left little more than the structural shell of the building.
[12] Uppark is a Grade I listed country house in England built around 1689. A serious fire occurred in 1989 and caused widespread damage throughout the building, including the loss of the roof. After the fire an authentic restoration was carried out, returning the house as close to the pre-fire situation as was possible.
[13] Rowell and Robinson, *Uppark Restored, 22.*
[14] 'Historic Royal Palaces' is an organisation responsible for six historic royal palaces, including the Tower of London and Hampton Court Palace.
[15] Crowdy, pers. comm.
[16] Administered by the Institution of Civil Engineers and The Institution of Structural Engineers.
[17] See for example https://ihbconline.co.uk/newsachive/?p=20539
[18] See note 9.
[19] Clandon Park is a Grade I listed country house in England, completed in 1731. The fire, which started in an electrical distribution board in the basement, gutted 95% of the interior of the building; the roof and internal floors were lost and post-fire little more than the structural shell of the building remained.
[20] Owen-Hughes, pers. comm.
[21] Murray, pers. comm. (2020).
[22] Echlin, pers. comm.
[23] Associated Press, *Notre Dame rector: Fragile cathedral;* France 24, *A rare look at restoration*; BBC, *Rebuilding Notre Dame*.
[24] BBC, *Rebuilding Notre Dame.*
[25] France 24, *Delicate work of dismantling*.

[26] Where Section 78 (Dangerous building—emergency measures) of the Building Act, 1984 applies.
[27] Ewing, pers. comm.
[28] Murray, pers. comm. (2019).
[29] Ridout, *Timber decay in buildings*, 142.
[30] Fishlock, *The Great Fire at Hampton Court*, 35.
[31] See note 13 above, 58.
[32] Murray, pers. comm. (2018).
[33] See note 30 above.
[34] See note 29 above.
[35] See note 32 above.
[36] See note 32 above.
[37] See note 10 above.
[38] Guardian, *Notre Dame cathedral sealed*.
[39] New York Times, *Notre-Dame's Toxic Fallout.*
[40] Smithsonian Magazine, *Notre-Dame Restoration Delayed*.
[41] See note 24 above.
[42] See note 30 above, 36.
[43] See note 13 above, 25.
[44] Historic England, List Entry for Nostell Priory.
[45] See note 30 above, 38.
[46] Ibid.
[47] Fishlock, *The Great Fire at Hampton Court*, 40; Nicolson, *Restoration, the rebuilding of Windsor*, 64.
[48] The National Trust, *Uppark*, 40.
[49] Spring, *The Caretakers*.
[50] Nicolson, *Restoration, the rebuilding of Windsor*, 64.
[51] For example, with the use of fire blankets.
[52] Ridout, *Timber decay in buildings*, 149-150.
[53] See note 30 above, 39.
[54] See note 50 above, 110.
[55] See note 50 above, 40.
[56] The Historic Buildings and Monuments Commission for England; commonly known as English Heritage and renamed as Historic England in 2015.
[57] See note 50 above, 108-114.
[58] See for example The Financial Times, *France doubts it will hit target to rebuild Notre-Dame in 5 years*; https://www.ft.com/content/429cb36e-dd27-11e9-9743-db5a370481bc.
[59] See note 13 above, 69-70.
[60] See note 50 above, 116.
[61] See note 50 above, 145.
[62] See note 30 above, 46.
[63] See note 30 above, 49.
[64] Science News, *After the Notre Dame fire*.
[65] Ibid.
[66] Association des Scientifiques au Service de la Restauration de Notre Dame de Paris.
[67] See: https://www.scientifiquesnotre-dame.org/
[68] Science News, *After the Notre Dame fire.*
[69] Brown, pers. comm.
[70] Ibid.
[71] See note 24 above.
[72] Daily Record, *Hero firefighters say Glasgow*.
[73] See note 68 above.
[74] See note 69 above.
[75] Ibid.
[76] SPAB, *The SPAB approach*, 17.
[77] Ibid, 18.
[78] At Uppark 250 craftspeople were eventually involved in the near-authentic reconstruction (Rowell and Robinson, *Uppark Restored*, 168.

[79] Le Monde, *Y aura-t-il assez.*
[80] See note 13 above, 73.
[81] Ibid.
[82] Grinling Gibbons was a 'Master Carver to the Crown' in the late 17th century, and his very high quality carving, mostly in wood but also in marble, is to be found in some of England's finest and most important buildings.
[83] See note 30 above, 92.
[84] "Adaptation means changing a place to suit the existing use or a proposed use." Australia ICOMOS, *The Burra Charter*, 2.
[85] Australia ICOMOS, *The Burra Charter*, 7.
[86] See note 13 above, 67.