The Likelihood Of Entanglement When Bats Meet Breathable Roofing Membranes

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ABSTRACT

Traditional roofing felt such as bitumen felt, has for the past century been considered a safe option for use within bat roosts, with only rare reports of problems. Modern roofing methods favour non-woven materials such as breathable roofing membranes (BRMs) and since their introduction into UK roof construction around 15 years ago, the production of non-woven materials has more than trebled. However, most modern BRMs are thought unsuitable for use within bat roosts, following a number of reports and anecdotal evidence of death through entanglement in fibres which have been pulled loose. Through the study of bat claws and modification of industry standard testing methods, we have investigated the likely outcome of bat interactions with these membranes. The preliminary results presented show that whilst industry tests consider standard stresses within a roof, they do not give an accurate interpretation of what happens when bats come into contact with such membranes. The likelihood of entanglement in a number of roosting scenarios is discussed. The ultimate aim is to use the data to aid the production of clear mitigation guidelines for use by those working towards bat conservation and those in the roofing industry wanting to meet increasing energy efficiency targets by using modern roofing materials.

Keywords
Bats, Roofing Membranes, Entanglement, Conservation

1. INTRODUCTION

During the past 20 years roofing construction methods have undergone significant changes in an attempt to aid the creation of more sustainable housing. The drive to increase a building’s overall energy efficiency has led to the introduction of numerous new materials to help meet continually evolving building regulations.

Non-woven materials, such as breathable roofing membranes (BRMs), are a good example of where this has occurred. Since their integration into UK roof construction around 15 years ago, the production of these textiles has more than trebled. Although the introduction of new materials, such as BRMs, may help increase levels of sustainability within the built environment, true sustainability needs to balance these needs with those of the natural world. Biodiversity also plays an important role in sustainability within the built environment and as bio-indicator species, bats are an important component of urban biodiversity.

Following bat population declines over the past century, bats are afforded the highest protection UK, and with 50% of British bat species now classed as building dependant, they
are a critical resource for bats providing safety and the correct environmental conditions (Brigham et al., 1997).

Since the introduction of BRMs into roofs where bats are found roosting, there have been reports of entanglement. This paper aims to consider the likelihood of entanglement occurring when a BRM is fitted into a bat roost. This will be done through engaging with literature and adapting it to the development of new and novel testing methods.

2. BACKGROUND

Over the past century the performance of bitumen felt, as described in BS747 (BS747:2000), in bat roosts has been considered a safe option, with only rare reports of problems. However, modern roofing methods favour the use of BRMs for their cost, ease of use and reduced need for ventilation. Yet recently most modern BRMs have been deemed unsuitable for use within a bat roost, following reports and anecdotal evidence of death through entanglement in filaments which have been pulled loose from the BRMs surface (Waring et al., 2012).

2.1 Structure of BRMs

BRMs typically comprise layers of spun-bonded polypropylene or a polypropylene and polyethylene mix, laminated either side of a functional vapour permeable layer (Albrect, 2003; BBA, 2004). During production these filaments are extruded onto a moving conveyor belt as a randomly orientated web (Wilson, 2007). The web is then thermally bonded with further non-woven webs or other products to produce a laminate, the layers of which are often then fixed using point bonding (Massenaux, 2003; Bhat, 2007). Within the UK there are over 60 brands of BRM available on the market, all of which are produced using polypropylene fibres.

2.2 Bats Use Of Roofs

In the UK many bat species have successfully adapted to roost in man-made structures (Lourenço and Palmeirim, 2004) and all species of British bat will make use of buildings to a varying degree (Williams, 2010); but for many species, buildings have become an essential source of roost sites, either through loss of natural roosts or because built structures offer preferable conditions (Entwistle et al., 1997).

Bats can be found roosting in both new and old buildings, although a greater number of roosts and wider range of species have been recorded in older buildings (Briggs, 2004; Simon et al., 2004; Williams, 2010). A preference for older buildings can mean bats often occupy buildings where renovation work is required. This can cause problems as maintenance activities in buildings can prove catastrophic for bats as seen with the use of remedial timber treatments (Stebbings, 1995).

The roof offers many roost sites both external and internal. Principal external sites are under ridge tiles, within the eaves or squeezed between tiles/slates and the roof underlay beneath (Hutson, 1993; Richardson, 2002; Agnelli et al., 2010). The narrow gap between the underlay and exterior roof covering is sufficient for a wide range of British species. Within the internal roof space bats may roost either along the ridge, around the gable ends (Hutson, 1993), in crevices behind fixtures (Simon et al., 2004), in close contact with timbers (Mitchell-Jones et al., 1989) or directly against the roofing underlay.

2.2.1 How bats attach to BRMs
To facilitate roosting from various surfaces, bats have long, keeled claws on their toes which are designed to hook onto suitable substrates (Cartmill, 1985). The claws are extremely sharp, so bats can grip onto very smooth surfaces, whilst the toes can be spread to provide grip at different angles and improve purchase (Dietz et al., 2009). Bats are also very active crawlers, with both fore and hind limbs employed in fast locomotion, scuttling hanging from and crawling along roost surfaces (Orr, 1971).

The feet support the main weight of the bat, but most UK species also use their thumb claws to improve grip. This ensures the bats entire body is in contact with the surface (Richardson, 2002).

3. THE NEED FOR RESEARCH

Although still widely cited for the specification of roofing underlays and membranes, BS747 felt was withdrawn in July 2007 (Stirling, 2009). Whilst it is believed that traditional felts will still be widely available (Garrand, 2008), the drive to meet stricter building regulations means the use of BRMs will continue to increase.

In 2002 the building and roofing industries accounted for 12.5% of the total non-woven materials used in Europe (EDANA, 2004). These statistics are important when considering bats often occupy buildings in need of remedial work. Demolition, renovation and change of use have often been overlooked for their importance in preserving bat colonies. Such changes in roosts can represent a major factor affecting bat populations (Agnelli et al., 2010). Where proposed developments will affect sites known to be used by bats, consideration needs to be given to the likely impact on the population. Even when planning permission is given, or no such consent is required, the wildlife legislation applies; bats and the places they roost are protected (Mitchell-Jones, 2004).

4. REPORTS OF PROBLEMS

Rumours of bats becoming entangled in sagging materials (Morris, 2008) and entangled in BRMs that have had spun-bond polypropylene filaments pulled loose, through use by bats, is the main reason research into this area was undertaken. Recently concerns over the use of BRMs within bats roosts have been substantiated with reports of problems including that of entanglement. These reports have also provided anecdotal evidence of the issues raised and the potential for future complications. The images below (Figures 1 & 2) show the ‘fluffing’ that can occur when spun-bond filaments are pulled loose through contact with bat claws, and the way such filaments can then become entwined around the bats limbs or body.

![Figure 1 – Visible ‘fluffing’ of membrane where bats have been roosting](image1)

![Figure 2 – Pipistrelle bats found dead having become entangled in loose fibres](image2)
5. NOVEL APPROACHES TO DETERMINE BAT FRIENDLINESS

5.1 Relevance of Current methods

In order to test mechanical strength BRMs are subjected to tear tests to determine tear strength (BSI, 2000). While tearing is a familiar phenomenon, few attempts have been made to understand it (Witteveen and Lucas, 2000). In order for a BRM to perform well in a tear test the filaments need to be strong and mobile, this allows them to reorient and straighten out. As a result a tear will not propagate as the strong filaments remain intact and continue to re-orientate and straighten as point bonds break.

This level of industrial testing may represent stresses encountered under standard conditions, however, they do not account for interactions with bats. Bat claws will often grab clusters of spun-bond fibres when gripping the BRM. These fibres can then be teased apart resulting in visible ‘fluffing’ on the membrane surface which can then pose an entanglement threat (See Figure 1&2).

5.2 What Is The End Point?

In order to classify a membrane as failing, it was important to consider what should be classed as the end point.

In respect to the BRMs the end point would be when sufficient damage had been caused that functionality was compromised. However, the chances are that this endpoint would be secondary to that required to ensure bat safety. Following investigations of photographs from reported incidents and samples of membranes where bats have been found entangled, it became clear that problems for bats begin when loose fibres form loops. This means that both ends of the filament are still attached and therefore could pose an entanglement threat. For this reason the endpoint of these tests will be set as when one or more loops of fibre can be seen across the majority of test samples.

5.3 Developing methods

In order to achieve this endpoint and ensure it resembles the damage seen from real world scenarios, the tests will need to simulate the conditions where BRMs are installed into bats roosts. Prior to this study, limited research has been carried on either bat claw morphology or how bats interact with breathable roofing membranes and so in order to determine if a membrane can be classed as ‘bat friendly’ we needed to consider such factors and how they could be reproduced within a laboratory scenario. This required investigation into several different methods, to best mimic how a bat claw would interact with the BRM within a roost.

5.4 Mimetic Claw

The initial idea for a test method was to make a mimetic bat claw that could be dragged along a membrane and the results recorded. In order to do this analysis of bat claws was required.

In the early stages of the project data was collected using a modified method for measuring raptor talons (Pike and Maitland, 2004). A total of 225 specimens were studied; specimens that were of sufficient quality had a variety of measurements taken. Claw length and claw width (measured using methods from (Dietz et al., 2009)), arc length (AL₀ for outer and AL₁ for inner), chord length (CL₀ for outer CL₁ for inner) and curvature radii measurements were taken on macro photographs of the claws using AutoCAD 2011.
5.4.1 Modified Sled Test

Adapted from ASTM D1894 (D20 Committee, 2011) the modified sled test incorporated a mimetic claw based on the average dimensions calculated from the measurements above. The claw was an adapted barbless fishing hook which was attached to the arm of the sled rig. This arm could be altered to adjust the hook angle of incidence and the weight applied to the tip of the hook, thus allowing determination of significant test parameters. The frame holding the membrane in place consisted of a backboard for the BRM to sit on and a top frame to clamp the membrane and prevent it from moving during the test. The sample of membrane held in the frame is 100cm (+/-0.5cm) x 300cm (+/- 0.5cm). This allowed for each sled test to cover a distance of 100cm along the length of the material. The sled was attached to an Instron machine with a 1KN load cell via a pulley to convert horizontal movement into vertical, and placed upon the secured BRM sample. Following setting of the claw angle of incidence and weight applied the test was started. During these initial tests both qualitative and quantitative data was recorded.

5.5 Modified Martindale Abrasion

The standard abrasion test (D13 Committee, 2012) using the Martindale tester (Figure 3) was adapted so that the abrading surface was placed in the moving section of the machine. This was to better mimic the movements of bats. The test was carried out using the minimum weight of 3KPa available and using 3 different abradants – standard Worsted wool, mole fur (bat fur mimic) and Velcro. The tests were run for 100, 500, 1000 and 5000 cycles and the qualitative results recorded (Figure 4).

![Figure 3 – Martindale tester](image1)

![Figure 4 – membrane following 500 rotations with Velcro abradent](image2)

5.6 What We Learnt

The novel methods used above did not accurately portray bat claw interactions with BRMs and so did not imitate the pattern of damage we see from samples taken from the real world. The adapted sled test with mimetic claw, although the claw was fully adjustable to mimic that of bats, was too sturdy. Rather than gripping fibres and then releasing, it constantly dragged through the material tearing fibres. The forces required to do this would not be possible for a bat to induce and so this method was considered unsuitable. The Martindale is a flat abrasion tester that ensures continuous contact between the test piece (BRM) and the abradant (bat fur mimic). Initial tests with the standard abradant, worsted wool, showed some signs of damage and so we progressed to use the bat fur mimic (mole...
fur). The results from this showed that the bat fur would become matted and damaged before the BRM and so this test showed that the fur contributes little to the pulling loose of fibres seen. The next adjustment was to use the hook side of Velcro, the idea being that the small hooks would grab fibres and due to the flexible nature of the product would release them without ripping the membrane, therefore matching what we see in reality. However, whilst the Velcro looked very promising as a tool in developing this test method, the constant flat abrasion and the minimum load applied to much pressure and the material was torn apart (Figure 4). From these previous tests we learnt that Velcro performs in a similar way to a bat claw when attaching to a BRM, but that constant abrasion was not an applicable test method. A test was needed that allowed the Velcro to attach and then release from the BRM to create a ‘plucking’ of the filaments.

6. METHODS AND MATERIALS

6.1 Modified Pilling Tester

The pilling tester (Figure 5) was set up according to ASTM D3512 (D13 Committee, 2010), however, this was altered by removing the spikes set up inside the box and lining the inside with standard grip Velcro strips. Three strips were placed on each of the six box faces, in differing directions to allow for a more realistic test (Figure 6). The membrane samples were then fitted to the standard rubber tubes using double sided tape and placed in the box. The samples were then tested at intervals of 50, 100, 250, 500, 1000, 1500, 2000, 3000 and 5000 rotations. The failure point was noted and samples kept for further analysis.

7. RESULTS

The results gathered from the pilling test experiments (Figure 7) showed that 13/18 membranes tested failed before 1000 rotations in the pilling box, five of these failed before they were even tested, due to the number of loops present in the finished product. Those products of the standard BRM type that did reach or exceed 1000 rotations all showed some variation in the type of point bond used. WG1 had not failed the test at 70,000 rotations, although there were signs of damage the test was stopped at this point.
8. DISCUSSION

8.1 Likelihood of Entanglement

The chance that a BRM has the potential to entangle a bat is linked to the BRM in question. The fibres produced during manufacture of non-woven BRMs are extremely strong as they are designed to protect the functional layer from environmental exposure and mechanical damage through movement. They are also extremely long, which allows fibres to form an entangled web, which holds the fibres together.

The results do appear to show that increased levels of point bonding can increase the length of time before loops appear on the membranes surface. Membrane FS2 has a metallised coating applied to the back surface and so the point bond on the front surface appears deeper than that of FS1, which is virtually the same product without the coating. The two membranes that didn’t fail until 5000 rotations (MP3 – back and MB1 – front) both showed signs of double point bonding; however, this can have a detrimental effect upon the membranes performance, and is only applied to one side of the membrane.

WG1 is a woven breathable membrane and so has different properties to the other eight BRMs tested. At 70,000 rotations the membrane showed visible signs of damage, mainly to the edges of the membrane, but no loops had formed and so the risk of entanglement was insignificant.

The results from these tests would suggest that whilst some membranes may have one surface that lasts longer under this testing method, all the non-woven types of BRM reached the test end-point within a relatively short period of time. This leads to the conclusion that it is the fundamental structure of these products that poses a risk of entanglement to bats. Therefore, the likelihood of entanglement when BRMs are placed into a bat roost is merely a question of time.

9. FURTHER PROGRESSION

The test devised in this paper is in its early stages and therefore needs to be improved to increase its robustness. This will involve altering the standard tubes to account for the bats weight and forces involved within real world situations. The method of quantifying the damage done to the membranes will also require the incorporation of microscopy.
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