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ISSUES WITH MANAGEMENT, MAINTENANCE AND UPKEEP IN ETFE ENCLOSURES

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1 INTRODUCTION

Ethylene tetra-fluoro-ethylene (ETFE) foil, as a single layer or as multi-layer inflated cushions, has been in used in the building industry for nearly 30 years as a medium to cover and clad both façades and atria. Its longevity has been well publicised and proven with many projects showing little or no signs of degradation.

The number of ETFE foil structures has been steadily rising in recent years, and with this the inevitable need for maintenance has also risen. The anticipated life of ETFE foil is now suggested to be as long as 50 years [1], and as with any other building material, regular inspections are necessary to ensure the continued optimal operation of the enclosure.

2 CASE STUDY 1 – HREOD DOME

Figure 1. ETFE cushion roof covering atrium of Nova Hreod College courtyard

An installation by Architen Landrell Associates in the UK, the Hreod Dome is an open structure in the South of England which covers the courtyard of Nova Hreod College (A new development in 2005 to relocate Hreod Parkway School). The dome comprises a radial array of fritted (printed) 2-layer ETFE cushions with a centre 'oculus' cushion. The ETFE cushion roof, located 15m above ground level, was chosen to cover the courtyard and provide a sheltered communal space for students as well as allow trees and plants to grow in the covered area.

The school is located within a kilometre of a decommissioned waste recycling site. The proximity to this site has resulted in a large number of birds in the vicinity; consequentially there have been occasions where maintenance is required due to damage to the cushions by the birds pecking at the surface. Often the necessity for remedial work is not immediately noticed and reported; small holes in the foil are easily offset by the capacity of the air handling units and although the internal pressure may be maintained, the pressurising fan will need to operate for longer and/or more frequently to replace the leaking air. Regular monitoring may potentially reveal such defects through the detection of abnormal fan usage.

Following the unusually cold winter with a large amount of snow, emergency work was necessary due to water ingress through a puncture in the cushion. In this case a site inspection revealed that the oculus cushion had deflated due to the size of the puncture. This resulted in the cushion inverting under the weight of snow and allowing water from the melted snow to enter the cushion. After the cushion was drained of water the hole could be patched using adhesive ETFE tape. The root of the problem was the unusually large volume of snow over the early months of 2010. This had caused the bird wire (used to prevent birds from landing on the aluminium extrusion) to be pulled from the holders, enabling birds to then land on the perimeter of the cushions. This also provoked a redesign of the bird wire holders to ensure they were more resilient to the load imposed by sliding snow.

Figure 2. Water pooling on and inside centre oculus cushion of ETFE roof

The perimeter of the dome allows full access for maintenance personnel however due to the circumferential design of the dome; there is no walkway for access to the top of the structure. This was taken into account during the design process of both the steelwork that supports the roof as well as for the extrusion that holds the perimeter of the cushions.

Figure 3. Steelwork with hanger plate anchor (indicated) designed for installation and maintenance access

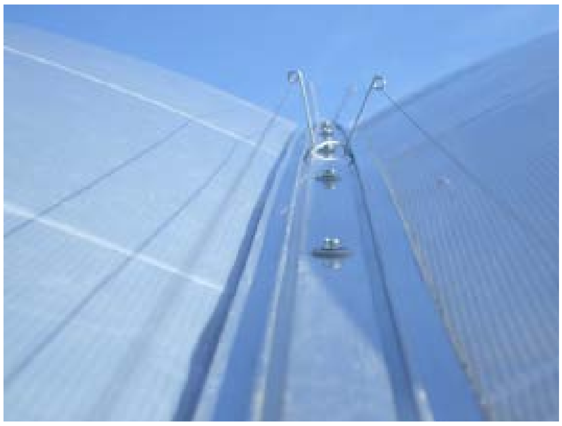

Figure 4. Aluminium extrusion used for securing edges of ETFE cushions

A channel in the steelwork allows safe contractor access to the oculus (Figure 3). Hanger plate anchors were applied at regular intervals on the steelwork channel to provide access to the top of the structure by qualified personnel. Additionally the extrusion is wide enough to allow trained maintenance crew to gain access to interim cushions that are not located directly next to the steelwork (Figure 4).

In this instance the access and repair of the ETFE cushion took no more than 2 hours; also including a routine inspection of the air handling unit (AHU) to ensure that the system continued to perform optimally.

3 CASE STUDY 2 – HERTFORDSHIRE UNIVERSITY

Figure 5. ETFE cushion entrance walkway at Hertfordshire University's Art & Design department

Approximately 10 years old and having had few inspections and very little maintenance in that time, the structure consists of a series of nine ETFE inflated cushions (with an area of nominally 225m^2) covering the general public access space to the Art and Design building. The walkway comprises three ETFE cushions forming the North face of the structure, and six inflatable cushions forming the South face; all cushions are constructed from translucent white ETFE.

Architen Landrell Associates was called to site to perform general maintenance on the structure due to a steady decline in pressure in the system due to apparent damage to the cushions. The maintenance brief involved repairing any damage to the cushions, an inspection of the air supply, cleaning of the top side of the ETFE cushions and cleaning the aluminium extrusion at the perimeter of the cushions.

Upon closer inspection of the cushions, it was found that some remedial work had previously been undertaken for small punctures that had been caused by birds pecking at the surface (Figure 6 & Figure 7) however since the system was last inspected there was a significant amount of additional damage to the surface. This was potentially the cause of the pressure drop in the cushions (the symptom being the fans running more than normally) and additionally allowing dirt deposits in the cushions through water ingress (Figure 8).

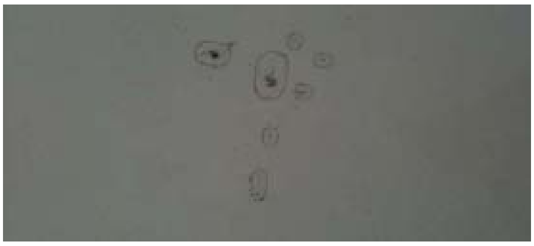

Figure 6. Existing repairs to ETFE surface

Figure 7. Additional damage as a result of birds pecking at surface

Figure 8. Dirt deposits as a result of water ingress

The air handling unit was serviced in order to ensure the cushions could achieve their full inflation pressure (nominally around 300 Pa) and to reduce the necessity of having the fans running constantly. This process involves ensuring the air supply manifolds have sufficient sealing, a check on the electronics and replacement of filters (if any) to ensure satisfactory continued operation. In this case a suspected cause of inadequate pressure in the cushions was that the filters did not appear to have been changed for a considerable time.

Figure 9. Clogged filter contributing to restricted air flow

Figure 10. New filter to replace old

Dust and particles in the air drawn in to the air handling unit and caught in the filter (in place to prevent these particles from entering the cushion) had clogged up the air intake, reducing the amount of air that was able to be pumped into the cushions and contributing to the drop in pressure. Figure 9 shows an image of one of the filters before it was replaced with a new one (Figure 10). This not only highlights the need for regular maintenance inspections by the installer to ensure continual satisfactory operation of the system, but also the need for repair kits to be located on s ite to enable building management services to diagnose and remedy simple maintenance issues with the ETFE systems. Good practice at hand-over of the structure would be to include information on regular maintenance of the roof within the Operation and Maintenance (O&M) manual (including topics such as frequency of filter changes) that can be performed by building services. This will aid in diagnosing and remedying simple matters that arise over the life of the structure.

4 CASE STUDY 3 – BARNSLEY INTERCHANGE

Figure 11. Entrance to Barnsley Interchange Station showing externally visible array of ETFE cushions

In December 2010 a problem was reported with an ETFE structure at Barnsley interchange railway station; a cushion was not inflating and there was concern over snow and ice build-up. It was also reported on site that following a recent air inflation pump change full inflation had not been achieved in the two cushions which had suffered ponding due to the weight of snow.

A site-visit showed that a combination of sunlight and warm air in the cushion had melted the snow and with subsequent sub-zero ambient temperatures the water had frozen in the inverted cushion and become sheets of solid ice (Figure 12 & Figure 13).

Figure 12. Image of ice build-up on cushions as a result of ponding

Figure 13. Image showing ice build-up of approx. 3”

The resulting weight of the ice that had pooled on one of these cushions also appeared to damage a previous repair, detaching a seam that was held with ETFE repair tape. Opening of this seam seemed to be the cause of the pressure loss in the cushions, and not (as was initially thought) the service that was performed previously on the air handling unit.

Figure 14. Ice sheet being removed from ETFE cushion

Figure 15. Previous repair of split weld possibly due to weight of ice

These symptoms might possibly be attributed to the initial design of the structure in particular the patterning of the cushions, the design of which builds in sufficient cushion rise to reduce the lateral forces on the supporting steelwork. Comparing a cushion with a higher radius of curvature than the cushions shown here (under equal pressure) the lateral loading on the steelwork will be higher. This is often visually desirable as it can produce a pleasing aesthetic to the building; however this could result in the issue discussed above in addition to increasing the amount of supporting steelwork which will have to be more substantial to allow for the higher loads.

5 CONCLUSION

As with any structure, for ETFE systems it is necessary for building management to actively participate in the maintenance of the structure. This can be achieved by performing regular checks and preventative maintenance on the foil, the perimeter and the air handling units. By carrying out these checks it is possible to avoid instances where more substantial remedial works may be necessary and to ensure continuous effective operation of the structure.

Likewise it is also the duty of the installer to provide information to the building management team on how best to look after the ETFE system. This should involve sections in O&M manuals that cover what checks should be made, how often, and what actions they can perform to keep the system at optimum health. This can also include information on how often user-serviceable parts, such as filters, should be maintained. To ease these processes it must be considered in the design phase of the structure to allow safe access to the structure to perform visual checks to both the ETFE and the air handling units.

Additionally, as with any low-profile roof, the risks of ponding or snow build-up (potentially leading to issues were cushions could be damaged) should be taken into account at design stage to minimise those risks.

6 REFERENCES

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