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TECHNICAL NOTEBOOK

Testing techniques to solve roofing problems

Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy and tensile testing were used to characterize a fully adhered EPDM roofing membrane that had exhibited surface degradation, amounting to the system failure.

The results obtained from these techniques suggested that the cause of failure could be attributed to the rubberized asphalt adhesive. Potential applications of combining both mechanical testing and chemical characterization as an aid to solving roofing problems are discussed.

Introduction

Investigating roofing failures usually implies obtaining samples of the failed roof and subjecting the samples to mechanical testing. This approach is acceptable; however, it does not necessarily assist in solving the problem. All that is known is that the material passed or failed a particular test.

A comprehensive approach is required to explain a failure which is not related solely to structural properties. Optimum solutions to roofing problems are greatly assisted by multi-technique approaches including mechanical testing and chemical analyses.

Useful techniques for chemical analyses include FTIR spectroscopy, SEM, thermal analysis and energy dispersive X-ray spectroscopy. The international roofing industry is now attempting to adopt a strategy that includes some chemical analyses (mainly thermal analysis) for the characterization of roofing membranes[1-5]. Other techniques could, however, also assist in solving roofing failures.

This paper presents a case where a combination of tensile testing and chemical analyses was used to find the cause of failure of a reinforced EPDM roofing membrane. Prior to the failure of this membrane, brownish stains had been observed on the surface of the membrane. It was also noted that this discoloration was even more apparent when a heavy rainfall followed an unusually high temperature period. The origin of the brown stain as well as the cause of brittleness of the EPDM membrane was investigated.

Experimental

The following samples were taken from the site of the failed roof:
a) EPDM membrane showing extensive brown stains; b) EPDM membrane without any discoloration or deterioration; c) EPDM membrane without any discoloration or deterioration from a different area of the roof; d) a new and unused EPDM Type II membrane; e) rubberized asphalt adhesive.

All the samples were tested and analyzed using the following techniques:
i) tensile tests; ii) scanning electron microscopy; iii) energy dispersive X-ray spectroscopy; iv) fourier transform infrared spectroscopy.

Tensile tests

Tensile strength and elongation properties of the membrane were carried out at room temperature using a universal testing machine (Instron tensile tester model 1122) with a gauge length of 60 mm and cross-head speed of 60 mm min^{-1}. The load and elongation curves were recorded on a machine chart recorder. All specimens were tested in tension to rupture after removing the adhesive from them.

Scanning Electron Microscopy

SEM was used to investigate the surface degradation of the various samples. A Cambridge Stereoscan 250 with a magnification of 50X was used to study the various samples.

Energy Dispersive X-ray Spectroscopy

The microanalysis of the surfaces of the sample was conducted using a Tracor Northern 5500 Energy Dispersive X-ray Analyzer. The test area and depth penetration are generally small, and hence, quantitative analysis was difficult. Consequently, this technique only was used for qualitative purposes.

Fourier Transform Infrared Spectroscopy

The FTIR analyses were carried out using a Nicolet SX-170 spectrometer equipped with a MCT detector. A resolution of 4 cm^{-1} was used and the spectra were recorded in the transmission mode.

Results and discussion

Tensile tests

The results obtained from tensile testing are tabulated in Table I. The breaking energies of the samples indicate that the sample with heavy discoloration was significantly different from the others. Samples with only slight discoloration exhibited similar tensile properties to the samples with no discoloration. Overall, the sample with continuous discoloration—the one with the highest surface degradation—had the poorest strength, elongation and energy at break valves.

Table I. Tensile tests on EPDM samples taken from the discolored roof

Brown Stain	Adhesive	Kerogen	EPDM
3406 s	3400 s	3400 s	
2904 vs	2905 vs	2924 vs	2920 vs
2834 s	2833 s	2833 s	2836 s
1705 s	1691 m	1700 m	
1596 sh	1576 m	1620 m	1547 s
1443 s	1430 m	1440 m	1466 m
			1404 m
1354 s	1326 w	1300 m	
1151 s	1171 m		

Intensities: vs=very strong; s=strong; m=medium; w=weak; sh=shoulder

SEM

The SEM micrographs indicated that more crazing was observed on the brown stained surface than on the unstained surface. The crazing pattern resembles that of a brittle material. Some microcracks were observed on unstained material but this was attributed to natural weathering/aging of the samples. The degradation seen in the discolored sample corresponds with the observed reduced tensile strength.

Table II. Vibrational data (cm^{-1}) for the brown stain, rubberized asphalt adhesive, kerogen and EPDM membrane

Sample		No. of Specimens Tested	Membrane Thickness (mm)	Strength N/25 (mm)	Elongation m/m %	Energy at Break MJ/m^3
ID	Surface					
A	Brown	4	1.34	168	481	15.4
B	Black	6	1.14	186	545	22.4
C	Black	4	1.25	198	629	27.5

Notes:

[1] The tests were done using 12 mm wide strips, since the amount of material available was insufficient to test according to ASTM D751, which requires 101.6 mm wide specimens.

[2] Each specimen had a representative number of strands of reinforcement.

[3] Sample C was placed on the roof 2 years later than samples A and B.

Energy Dispersive X-ray Spectroscopy

Three elements were detected as major components: sulphur, calcium and silicon. The EPDM membrane had, in general, a very strong sulphur peak. The calcium peak was attributed to the rubberized asphalt adhesive, while the silicon peak originated from atmospheric dust and sand. On the clean black EPDM membrane surface, where no adhesive was present, no calcium was detected. In the EPDM samples, where small amounts of adhesive remained, both sulphur and calcium peaks were present. The brown stain also was found to have intense sulphur and calcium peaks. This seems to suggest that some rubberized asphalt adhesive diffused through the EPDM membrane.

FTIR analysis

The FTIR spectra of the samples were typical of asphaltic[6] and rubber materials (see Table II). Peaks were observed in the CH stretching region (3000-2800 cm^{-1}) and CH bending region (1500-1300 cm^{-1}). The spectrum associated with EPDM was different from that of the brown stain which was scraped off from the membrane. The spectrum of the brown stain did, however, resemble more closely the spectrum associated with the rubberized asphalt adhesive and kerogen (the organic component of bitumen). The brown stain, the adhesive and kerogen all exhibited characteristic bituminous peaks; OH stretch (3600-3000 cm^{-1}), C=O stretch (1700 cm^{-1}), C=C stretch (~1600 cm^{-1}), C-O stretch (~1100 cm^{-1}).

The combination of the FTIR data and the energy dispersive X-ray data clearly indicates that the brown discoloration must have originated from the rubberized asphaltic adhesive.

Conclusions

The following conclusions can be made regarding the brownish discoloration:

a) The stain on the EPDM roofing membrane was a result of some fraction of the rubberized asphaltic adhesive diffusing through the membrane and being oxidized by atmospheric oxygen and solar radiation.

b) The brown residue is washed down the roof slope by rain water. This further exposes the asphaltic fraction diffusing through the deteriorating EPDM membrane.

c) The EPDM membrane undergoes ultraviolet-induced degradation. This process is increased by the presence of organic compounds, especially of the aromatic types. In the present case, the material which contained the brown residue contained aromatic compounds; hence, the EPDM degradation was accelerated.

d) The cause of surface degradation and membrane weakening is a combined effect of solar radiation and the diffusion of the asphaltic adhesive to the surface.

e) The diagnostics of this case demonstrate that no single technique can provide a complete explanation for the cause of roofing failure. The combination of mechanical tests and chemical analyses should be used to assess more precisely and completely the causes of roofing problems.

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