Accelerated Testing of Roofing Materials, Outline I

Strategy: summarize industry knowledge for new hires

Intro – Accelerated testing is most useful when actual weathering processes are understood

Artificial exposure to UV, moisture, and cyclic heating; equipment used

Cite literature information on

Synthetic polymer coatings
- -for metal roofing
- -for roof membranes
- -for clay tile
- -for concrete tile

Asphalts
- asphalt shingles
- asphalt roof coatings
- built up roofing

Roofing granules

Inorganic pigments
- -oxides
- -chalcogenides

Organic pigments

Case study I: Ferro/BASF data on complex inorganic pigments in PVDF coatings

Further case studies . . .

Weathering of Roofing Materials, Outline II

1. Introduction: list of main weathering stresses:

UV
Heat
Thermal shock
Temperature cycling
Moisture
Freeze thaw cycles
Wind
Chemicals: SO2, NO2, soil
Biological growth

2. UV damage

Photo-oxidation of polymers. Dependence on UV, moisture, temperature, oxygen diffusion
Photo-oxidation of asphalt
Photo-oxidation of organic pigments

3. Some Corrosion Chemistry

How metal roofing is protected
Thermal oxidation of asphalt
Chemical aging of concrete
Efflorescence

4. Mechanical stresses

Wind forces
Differential thermal expansion
Flexible materials less likely to crack

Combined Bibliography on natural and accelerated weathering of roofing materials

General/Introductory

C. G. Cash, Estimating the durability of roofing systems, in Durability 2000: Accelerated and Outdoor weathering testing, STP 1385, ASTM 165-169 (2000).

Weathering Test Methods, a paper on the Atlas Material Testing Technology website.

L. F. E. Jacques, Accelerated and outdoor/natural exposure testing of coatings, Prog. Polym. Sci. 25, 1337-1363 (2000).

Pigments, general

Peter A. Lewis, ed., Pigment Handbook, Vol. I, 1-945, John Wiley & Sons (New York, 1988).

ASTM 4302-99, Standard specifications for artist's oil, resin-oil, and alkyd paints. Pigments, Inorganic. Lightfastness data on more than 100 common artist's pigments.

Pigments, inorganic

G. Buxbaum, ed., Industrial Inorganic Pigments, 2nd ed., Wiley-VCH (1998).

J. H. Braun, Titanium dioxide's contribution to the durability of paint films, Prog. in Organic Coatings 15, 249-260 (1987).

J. H. Colling and J. Dunderdale, The durability of paint films containing titanium dioxide – contraction, erosion and clear layer theories, Prog. in Organic Coatings 9, 47-84 (1981).

R. E. Day, The role of titanium dioxide pigments in the degradation and stabilization of polymers in the plastics industry, Polymer Degradation and Stability 29, 73-92 (1990).

H. G. Volz et al., Surface reactions on titanium dioxide pigments in paint films during weathering, Prog. in Organic Coatings 2, 223-235 (1973/74).

Pigments, organic

W. Herbst and K. Hunter, eds., Industrial Organic Pigments, 2nd ed. Wiley-VCH (1997).

BASF technical information, Paliogen pigments for coatings (May 2001). Lightfastness data on some perylene pigments, including Paliogen Black L 0086.

Polymers

G. Wypych, Handbook of Material Weathering, 2nd ed., ChemTech Publishing, 38 Earswick Dr., Toronto-Scarborough, Ontario, Canada (1995). Despite title, this book is exclusively concerned with polymers.

R. R. Blakey, Evaluation of paint durability – natural and accelerated, Prog. Org. Coatings 13, 279-296 (1985).

R. P. Brown, Survey of status of test methods for accelerated durability testing, Polymer Testing 10 3-30 (1991).

R. P. Brown, Test Procedures for artificial weathering, Polymer Testing 12, 459-466 (1993)

B. R. Palmer et al, Titanium dioxide particles for protection of plastics from ultraviolet radiation, preprint circa 1995.

E. B. Ravinovitch and J. W. Summers, Infrared reflecting vinyl polymer compositions, U. S. Patent No. 4,424,292 (1984). PVC is made more durable in sunlight by reducing temperature.

S. G. Croll, Quantitative evaluation of photodegradation in coatings, Prog. in Organic Coatings 15, 223-247 (1987).

M. L. Ellingger, Weathering tests, Prog. in Organic Coatings 5, 21-34 (1977). Historical paper.

R. M. Fischer, Inherent variability in accelerated weathering devices, Prog. in Organic Coatings 19, 165-179 (1991).

Y. C. Jean et al., Early stage of deterioration in polymeric coatings detected by positron annihilation spectroscopy, Prog. in Organic Coatings 52, 1-8 (2005).

F. N. Jones et al., Artist paints – an overview and preliminary studies of durability, Prog. in Organic Coatings 52, 9-20 (2005).

G. Kampf et al., Studies in accelerated weathering. Part I. Determination of the activation spectrum of photodegradation in polymers, Prog. in Organic Coatings 19, 69-77 (1991).

P. E. Mallon et al., Durability of polymeric coatings: effects of natural and artificial weathering, Applied Surf. Sci. 194, 176-181 (2002).

S. P. Pappas, Weathering of coatings – formulation and evaluation, Prog. in Organic Coatings 17, 107-114 (1989).

J. Pospisil et al., Influence of testing conditions on the performance and durability of polymer stabilizers in thermal oxidation, Polymer Degradation and Stability 82, 145-162 (2003).

J. Boxhammer, Shorter test times for thermal- and radiation-induced ageing of polymer materials 1: Acceleration by increase irradiance and temperature in artificial weathering tests, Polymer Testing 20, 719-724 (2001).

S. Brunner et al., Accelerated weathering device for service life prediction for organic coatings, Polymer Testing 24, 25-31 (2005).

L. D. Suits et al., Assessing the photo-degradation of geosynthetics by outdoor exposure and laboratory weatherometer, Geotextiles and Geomembranes 21, 111-122 (2003).

W. Dierickx and P. V. D. Berghe, Natural weathering of textiles used in agricultural applications, Geotextiles and Geomembranes 22, 255-272 (2004).

N. J. W. Gamage et al., Factors affecting the photolysis of polyester-melamine surface coatings, Polymer Degradation and Stability 81, 309-326 (2003).

J. V. Gulmine et al., Degradation profile of polyethylene after artificial accelerated weathering, Polymer Degradation and Stability 79, 385-397 (2003).

I. Jakubowicz, Effects of artificial and natural ageing on impact-modified poly(vinyl chloride) (PVC), Polymer Testing 20, 545-551 (2001).

L. T. Keene et al., Failure of navy coating systems 1: chemical depth profiling of artificially and naturally weathered high-solids aliphatic poly(ester-urethane) military coating systems, Prog. in Organic Coatings (2005, in press).

D. Kockott, Shorter test times for thermal and radiation induced ageing of polymer material 2: Early recognition of molecular alterations by measurement of chemiluminescence, Polymer Testing 20, 725-727 (2001).

V. C. Malshe and G. Waghoo, Weathering study of epoxy paints, Prog. in Organic Coatings 51, 267-272 (2004).

N. M. Sanchez et al., Accelerated weathering and biodegradation of e-glass polyester composites, Int. Biodeterioration and Biodegradation 54, 289-296 (2004).

A. Miszcxyk and K. Darowicki, Effect of environmental temperature variations on protective properties of organic coatings, Prog. in Organic Coatings 46, 49-54 (2003).

M. E. Nichols and C. A. Peters, The effect of weathering on the fracture energy of hardcoats over polycarbonate, Polymer Degradation and Stability 75, 439-446 (2002).

M. Osterhold and P. Glockner, Influence of weathering on physical properties of clearcoats, Prog. in Organic Coatings 41, 177-182 (2001).

F. X. Perrin et al., Evaluation of accelerated weathering tests for three paint systems: a comparative study of their aging behavior, Polymer Degradation and Stability 72, 115-124 (2001).

J. E. Pickett, Reversible post-exposure yellowing of weathered polymers, Polymer Degradation and Stability 85, 681-687 (2004).

L. P. Real and J. L. Gardette, Ageing and characterization of PVC-based compounds utilized for exterior applications in the building construction field 1: Thermal ageing, Polymer Testing 20, 779-787 (2001).

L. P. Real et al., Artificial accelerated weathering of poly(vinyl chloride) for outdoor applications: the evolution of the mechanical and molecular properties, Polymer Degradation and Stability 82, 235-243 (2003).

J. Sampers, Importance of weathering factors other than UV radiation and temperature in outdoor exposure, Polymer Degradation and Stability 76, 455-465 (2002).

C. M. Seubert et al., The long-term weathering behavior of UV curable clearcoats I. Bulk chemical and physical analysis, Polymer Degradation and Stability 81, 103-115 (2003).

N. Tahmassebi and S. Moradian, Predicting the performances of basecoat/clearcoat automotive paint systems by the use of adhesion, scratch and mar resistance measurements, Polymer Degradation and Stability 83, 405-410 (2004).

G. F. Tjandraatmadja et al., Evaluation of commercial polycarbonate optical properties after QUV-A radiation – the role of humidity in photodegradation, Polymer Degradation and Stability 78, 435-448 (2002).

G. M. Wallner et al., Polymer films for solar energy applications - thermoanalytical and mechanical characterization of ageing behaviour, Polymer Degradation and Stability 85, 1065-1070 (2004).

Asphalt

J. Huang et al., Photooxidation of Corbett fractions of asphalt, Fuel Sci. and Technol. Int., 13 (9), 11211134 (1995).

J. C. Petersen, A dual, sequential mechanism for the oxidation of petroleum asphalts, Petrol. Sci. and Technol. 16 (9&10) 1023-1059.

G. R. Kemp and N. H. Predoehl, A comparison of field and laboratory environments on asphalt durability, Asphalt Paving Technol. 50, 492-555 (1981).

Y. Trolpsha and A. Andrady, Photodegradation of asphalt and its sensitivity to the different wavelengths of the sunlight spectrum, Polymeric Mat. Sci. and Eng., Vol. 66. Amer. Chem. Soc., p. 305 (1992).

ASTM D 4977-03, Standard test method for granule adhesion to mineral surfaced roofing by abrasion, 235-236 (2003).

ASTM D 3462-04, Standard specification for asphalt shingles made from glass felt and surfaced with mineral granules

ARMA technical bulletin, Application of asphalt shingles over insulation or insulated decks (July, 1996). Indicates elevated temperatures could be deleterious.

S. Bearsley et al, Direct observation of the asphaltene structure in paving-grade bitumen using confocal laser-scanning microscopy, J. of Microscopy 215, Pt 2 149-155 (2004).

W. J. Sicina, technical marketing manager, Perkin-Elmer, Characterization of asphalt roofing shingles using the diamond DMA. (DMA= Dynamic Mechanical Analysis). Stiffness and loss tangent as a function of vibrational frequency and temperature.

L. A. Terrenzio, J. W. Harrison, D. A. Nester, and M. L. Shiao, Natural vs. artificial aging: use of diffusion theory to model asphalt and and fiberglass-reinforced shingle performance, Proc. 4th Int. Symp. on Roofing Technol. 66-74 (Gaithersburg, Sept., 1997).

M. L. Shiao, M. L., Nester, D. A., and Terrenzio, L. A., "On the Kinetics of Thermal Loads for Accelerated Aging," Roofing Research and Standards Development, 5th Volume, ASTM STP 1451, W. J. Rossiter and T. J. Wallace, Eds., (ASTM International, West Conshohocken, PA, 2003).

Clay roof tile

One page essay on salt intrusion provided by MCA. $BaCO_3$ additives react with sulfate impurities. Resulting $BaSO_4$ is insoluble and benign.

Roofing granules

H. O. Laaly, Vol. 2, chap. 48 of The science and technology of traditional and modern roofing systems, p. 48-7 to 48-15. Essay on the history of roofing granules. Copy from 3M.

J. R. Brown, Granules, in Industrial minerals and rocks: (nonmetallics other than fuels), J. L. Gillson et al., editors, 443-454, Amer. Inst. Mining, Metallur. and Petroleum Eng. (New York, 1960). Copy from 3M.

J. L. Jacobs, Photocatalytic composition and method for the preventing algae growth on building materials, U. S. Patent No. 6,569,520 (2003). Anatase TiO_2 nanocrystals.

I. B. Joedicke, Color stable pigment for granular surface coated roofing and siding shingles, U. S. Patent No. 6,235,372 (2001).

Coated Metal

Boelen et al., A literature survey on the development of an accelerated laboratory test method for Atmospheric corrosion of precoated steel products, Corrosion Science 34, 1923-31 (1993).

J. L. Gerlock et al., Paint weathering research at Ford, Metal Finishing 99, 8-14 (May, 2001).

K. Adamsons, Chemical depth profiling of multi-layer automotive coating systems, Prog. in Organic Coatings 45, 69-81 (2002).

D. R. Bauer et al., Rapid, reliable tests of clearcoat weatherability: a proposed protocol, Prog. in Organic Coatings 15, 209-221 (1987).

D. R. Bauer, Interpreting weathering acceleration factors for automotive coatings using exposure models, Polymer Degradation and Stability 69, 307-316 (2000).

G. Bierwagen et al., EIS studies of coated metals in accelerated exposure, Prog. in Organic Coatings 46, 148-157 (2003).

O. Guseva et al., Service life prediction for aircraft coatings, Polymer Degradation and Stability 82, 1-13 (2003).

X. F. Yang et al., Weathering degradation of a polyurethane coating, Polymer Degradation and Stability 74, 341-351 (2001).

X. F. Yang et al., Blistering and degradation of polyurethane coatings under different accelerated weathering tests, Polymer Degradation and Stability 77, 103-109 (2002).

X. F. Yang et al., Degradation of low gloss polyurethane aircraft coatings under UV and prohesion alternating exposures, Polymer Degradation and Stability 80, 51-58 (2003).

Concrete

A. R. Kenney, Avoiding efflorescence in architectural precast concrete, Concr. Constr. 33 (6) 571-574 (1988).

K. A. Hooker, Reducing efflorescence potential, Mason. Constr. 7 (2), 76-79 (1994).

H. B. Newman, Everything efflorescent, Mason. Constr. 13 (9), 13-17 (2000).

C. D. Goode, Weathering of concrete, Concr. Constr. 36 (1), 44-54 (1991).

G. R. Fedor and P. J. Brennan, Correlation between natural weathering and fluorescent UV exposures: UVA-340 lamp test results, in R. J. Herling (Ed.), Durability Testing of Non-Metallic Materials, ASTM STP 1294, ASTM, Philadelphia, PA (1996).

Bayer, Efflorescence, a temporary problem, Bayer, Industrial Chemicals Division, Pittsburgh, PA (1997).

Wood

S. T. Chang and P. L. Chou, Photo-discoloration of uv-curable acrylic coatings and the underlying wood, Polymer Degradation and Stability 63, 435-439 (1999).

P. D. Evans, Effect of angle of exposure on the weathering of wood surfaces, Polymer Degradation and Stability 24, 81-87 (1989).

P. B. Evans et al., Weathering and photostability of benzoylation wood, Polymer Degradation and Stability 76, 291-303 (2002).