network group for composites in construction

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Fact Sheet 04

Predicting the weathering behaviour of fibre reinforced polymers for construction applications

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Durability is a key property for FRPs. They do not suffer from corrosion, from the biological decay that can rot timber, or from the changes that can affect concrete. However, like most materials, FRPs can be affected by environmental degradation. It is important to ensure that FRPs in construction achieve satisfactory levels of durability. As a result, the ability to predict the performance of a material and component in service is paramount.

Effects of weathering

The changes that take place when FRPs are exposed to weathering arise mainly from the effects of a combination of ultraviolet (UV) radiation and heat from the sun, together with the effects of moisture (precipitation and condensation) and oxygen from the atmosphere. If the component is buried in the soil, there may be microbiological activity, but this will not usually be a problem with the materials used in FRPs.

The effects of outdoor use on structural FRPs such as glass/polyester or carbon/epoxy laminates are confined to the surface and are usually cosmetic. As a result, they do not often involve a serious threat to their structural integrity, unless perhaps there is a reduction in impact strength as a result of surface cracking.

Prediction of weathering effects

In general, UV exposure tests for FRPs can be grouped into three main categories:

- Outdoor testing – specimens are directly exposed to outdoor conditions at a fixed angle relative to the horizontal and in a fixed direction
- Accelerated outdoor weathering – UV radiation is concentrated onto the test specimen using special mirrors
- Accelerated laboratory testing – specimens are exposed to UV radiation from a variety of UV light sources; filters are often employed to remove wavelengths which fall outside of the solar spectral range of interest. Equipment is also fitted with rain or moisture cycles to mimic the effect of rain.

Natural weathering

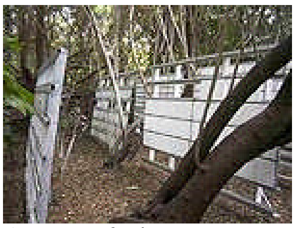
Climates can be classified into a number of types such as temperate, sub-tropical, desert, arctic and Mediterranean. Additionally they can be industrial, rural or marine in nature. The effects of weathering will vary in each climate, as well as from season to season and from year to year. Thus it is very difficult to compare the weathering performance of one material with that of another.

Natural weathering in Florida is often used as a means of forecasting more rapidly those effects that will occur in temperate climates. For example, one year's exposure in Florida is taken to be roughly equivalent to 4-5 years in central Europe. Such comparisons are necessarily approximate. However, Florida exposure often forms part of the specifications for weather resistance throughout the rest of the world. Figures 1 and 2 illustrate different outdoor test sites.

Fig 1: Outdoor test site

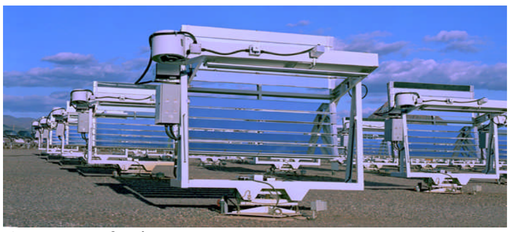
Courtesy of Atlas

Fig 2: Tropical forest test site



Courtesy of Atlas

Fig 3: EMMAQUA test rigs



Courtesy of Atlas

Accelerated outdoor weathering

The effects of weathering at locations such as Florida and Arizona can be accelerated by using panel mountings that track the sun, combined with Fresnel reflectors to concentrate the rays of the sun, water sprays and cooling devices. This method is known as EMMAQUA which stands for equatorial mounted mirrors with water spray (AQUA) as shown in Figure 3. By such means, one year of normal Florida weathering can be achieved in approximately 40 to 45 days. Therefore, this is a very cost-effective method for testing materials needing a long service life.

Accelerated laboratory weathering

Accelerated laboratory (artificial) weathering tests are widely used to investigate the durability of FRPs and other polymeric materials. These tests are based on the use of ultraviolet light, which is the principal agent responsible for the degradation of polymers. There are currently three key methods used for artificial weathering:

- Carbon arc
- Xenon arc
- Fluorescent lamps

<u>Carbon arc</u>

For the enclosed carbon arc, two strong emission bands peaking at 358 nm and 386 nm are much more intense than natural sunlight. This type of light source can be expected to have a weaker effect than solar radiation on materials that absorb only short wavelength UV radiation, because there is very little irradiance below 310 nm. This technology has largely been replaced with fluorescent UV or xenon arc systems.

<u>Xenon arc</u>

Xenon arc lamps give a broad spectrum of light that matches the solar spectrum quite closely. At the short wavelength end of the spectrum, the lamps produce a small amount of short wavelength UV light that is not seen in sunlight because it is filtered out by the earth's atmosphere. At long wavelengths, xenon arc lamps produce a larger proportion of near infrared light than is present in sunlight. However, filters can be used to correct for the greater part of these imbalances, producing a close match to a selected solar spectrum.

<u>Fluorescent lamps</u>

Fluorescent lamps have special phosphors selected to emit UV light at a particular waveband. Several types of lamp are available, concentrating their radiation either in the UV-A (400-315nm) or UV-B (315-280nm) wavebands. With either type of device, exposure to light is carried out under relatively controlled conditions of temperature and moisture.

Comparisons between accelerated and natural weathering

The inherent variability in both laboratory and outdoor exposure testing makes it extremely difficult to obtain acceleration factors for correlating laboratory and outdoor test results (i.e. x hours in accelerated test equals y years in an outdoor environment). Thus any correlations must be qualitative.

The use of reliable methods makes it possible to predict service lifetimes more accurately. Such methods involve the precise measurement of temperature, time-of-wetness, and spectral UV radiation (in outdoor and laboratory accelerated testing). In particular, the calculation of total effective UV dosage (the actual amount of UV radiation which induces photochemical reactions in a material) takes into account the fact that not all UV radiation is absorbed, and that not all absorbed UV radiation causes a photochemical reaction to occur.

Characterisation of weathering effects

UV-induced damage to FRPs can be assessed either by visual inspection, or by using analytical instruments that can detect changes in surface properties that the eye cannot discern. The most common methods used are:

- Glossmeter – measures specular reflectance of the surface
- Colourimeter – measures changes in colour related properties

Summary

FRP components are prone to surface degradation caused by exposure to UV radiation. This degradation normally has little effect on the mechanical properties of the material – particularly true for thick sections.

Any UV testing of FRPs should be undertaken with caution, whether testing is conducted outdoors or in a laboratory weathering device. Results of testing in outdoor environments are seldom reproducible, due to the highly variable nature of the weather and associated climatic factors. Thus, tests carried out on the same material are difficult to compare even if they were carried out at the same site and time of year. Laboratory testing gives better control over the environmental conditions to which specimens are exposed. The best methodology is to compare an unknown material to a reference material within a particular test run, or to rank materials within a particular test run. It is also known that UV degradation in FRPs (as in other polymers) is often accelerated by the application of mechanical loads, a capability that is not included in current existing test standards or weathering devices.