Plastics Industry Pipe Association of Australia Limited ACN 086 511 686

Weathering of PVC Pipes and Fittings

Alan Whittle, April 2010

Poly vinyl chloride (PVC) is similar to many other materials in that it is affected by weathering. This applies not only to other plastics, but also materials like timber and metals. Also, as for these other materials, it is possible to use preventative measures to protect against weathering.

However, whereas timber and metal products are usually protected with coatings such as paints or oils, the protective agent for PVC can be incorporated into the material itself. In the case of PVC pipes protection is achieved by adding at least 1.5 parts of the white pigment titanium dioxide (TiO_2) per 100 parts of PVC resin.

Note: *It is common to express the concentration of additives in rubbers and plastics as parts by mass of additive per 100 parts of polymer. This is abbreviated to 'phr'.*

PVC weathering

When unprotected PVC is exposed to sunlight, the ultraviolet radiation causes a series of complex reactions to occur which results in the degradation of the polymer. The degradation is accompanied by the formation of highly coloured compounds. In fact, the discolouration of unprotected PVC has been used as a quantitative measure of UV radiation[1].

The most common protective agent used in PVC pipes is titanium dioxide which absorbs most of the incident UV and visible radiation[2], thereby protecting the PVC molecules. For pipes and fittings in Australia, a coated form of rutile TiO_2 is used as this optimises the protection, minimises chalking and achieves good dispersion.

Exposure Studies

A large number of studies have been carried out on the protection of PVC from the effects of weathering. Two of the most important were performed by UNI-BELL[3] in the USA and the CSIRO[44] in Australia. Both studies involved the exposure of pipe samples to extreme weather conditions. For example, the CSIRO study was carried out on samples exposed at Broken Hill whilst the USA samples were exposed at 12 different sites.

As the CSIRO study was carried out in Australia using Australian made PVC pipes it has provided the basis on which TiO_2 requirements have been specified in the Australian/ New Zealand Standards for PVC pressure and non-pressure pipes.

The studies have shown that 1.5 parts of TiO_2 is sufficient to provide protection to PVC pipes. No significant advantage is gained by adding higher concentrations to pipes and fittings, although extra TiO_2 is often added to decorative products for aesthetic reasons.

[1] K. G. Martin, Monitoring ultraviolet radiation with polyvinyl chloride, B. Polym. J., 5, p443-450, 1973.
[2] C. E. Wilkes, J. W. Summers and C. A Daniels, Editors, PVC Handbook, Hanser Publishers, Munich.
[3] Uni-TR-5-03 The effects of ultraviolet radiation on PVC pipe, Uni-Bell PVC Pipe Association, Dallas, Texas.
[4] L. S. Martin, K. G. Martin and S. D. Terrill. Effects of titanium dioxide on the weathering performance of UPVC pipe, CSIRO Division of Building Research.

The Uni-Bell study showed that 2 years of exposure of PVC pipes to a variety of climatic conditions did not alter the bulk properties, tensile strength and modulus. The CSIRO similarly showed there was no change in the yield stress after 2 years exposure, irrespective of the TiO_2 concentration. That is, even without any pigment, the yield strength of PVC was not compromised by two years exposure to the weather at Broken Hill.

What did change according to the CSIRO report was the gloss of the pipe surface. There was a progressive reduction in surface gloss over a period of about 12 months, after which there was no further change.

Whilst the impact strength of exposed strips in the CSIRO study initially decreased before stabilising at about 3 months, pipes exposed for 2 years exhibited similar impact resistance to the pipes as made. Short-term exposure of some pipes actually resulted in an increase in impact resistance.

Australian Standards for PVC pipes

Australian Standards did not specify a concentration of TiO_2 until the 1980s. When the publication of joint Australian and New Zealand Standards commenced, it was agreed to nominate not less than 1.5 phr of TiO_2, based on the results of the various exposure trials, in particular that of the CSIRO. The progression of the Standards with respect to TiO_2 requirements is summarised below.

a. The 1974 edition of AS1260 for UPVC pipes and fittings for sewerage applications did not specify a TiO_2 content, only a colour (cream). In order to meet the colour requirements, TiO_2 was usually added. Moreover, some sewerage authorities had their own specifications for TiO_2 content. In the 1984 edition, AS1260 had a requirement for a minimum of 1 phr of rutile titanium dioxide. Note that sewer pipes and fittings were specifically intended for below ground applications. In 1996, the sewerage and SWV requirements of the relevant Australian and New Zealand Standard were all combined into AS/NZS1260 with 1.5phr of TiO_2 specified. This requirement has subsequently been extended to all PVC pipes.

b. The 1974 edition of AS1415 for pipes and fittings for soil, waste and vent applications required sufficient TiO_2 to meet the colour and opacity specifications. This was subsequently changed to not less than 2 phr then to 1.5phr with the publication of the combined AS.NZS DWV Standard in 1996.

c. Until 2002, the stormwater pipes and fittings Standard AS1254 did not nominate the minimum TiO_2 content, but this changed with the publication of the joint Standard AS/NZS1254 - 2002.

d. For pressure applications, it was only with the publication of joint Australian and New Zealand Standard AS/NZS1477 that the TiO_2 content of not less than 1.5 phr was nominated. Until then, manufacturers were required to add sufficient pigment to meet the opacity requirements. PVC-M and PVC-O pressure pipes, introduced later than PVC-U, have always required a minimum of 1.5 phr of TiO_2.

e. AS/NZS2032 Installation of PVC pipe systems states *If the total period of exposed storage outdoors is likely to exceed 12 months, pipes and fittings shall be covered and stored in a manner that allows ventilation and prevents heat entrapment. Pipes and fittings may be stored in this manner indefinitely.* This is considered to be very conservative and not justified on the basis of the exposure testing performed by the CSIRO and others. The testing exposure performed by the CSIRO indicates pipes stored outside for more than 12 months will perform as well as pipe stored outside for less than 12 months.

   Additional advice regarding the storage of PVC pipes and fittings and the selection of suitable materials for covering stored product is included in AS/NZS2032.

PVC Pipes in service

Older SWV pipes and fittings and now DWV pipes and fittings are often installed in applications where they are continually exposed to sunlight, without any adverse effect on service life.

Most often PVC pressure pipes and fittings are installed below ground, but it is not uncommon for them to be used in exposed installations in industrial applications and water treatment plants. Whilst it has been the recommendation of the plastics pipes industry to protect exposed PVC pressure pipes by painting them with a water-based paint, this has often been neglected with no apparent adverse effects. Where paint has been applied, it is more than likely the coating has not been properly maintained. There is no evidence to suggest the service life of exposed PVC pressure pipes has benefited from painting.

Conclusions

a. The studies confirm that titanium dioxide offers excellent protection to PVC pipes against UV radiation.

b. The optimum concentration of the pigment is 1.5 part by mass per 100 parts of PVC resin.

c. The titanium dioxide concentration of 1.5phr is adequate to provide protection during storage for at least 2 years and in fact is expected to provide protection against exposure to sunlight for the service life of the pipe in most applications.

Note: *Pipes and fittings exposed to high service temperatures must also be adequately protected against thermal degradation by the use of appropriate thermal stabilisers.*

d. There is no technical justification for limiting the storage life of PVC pipes and fittings to only 12 months as nominated in AS/NZS2032, now that all the Australian/ New Zealand Standards nominate a minimum concentration of 1.5phr of TiO_2.

Notes: *1. Non-white pipes exposed for extended periods might exhibit signs of fading or chalking on the exposed surfaces but this is only a surface effect. The hoop strength and the stiffness of PVC pipes are not altered by this fading or surface chalking.*

2. Special, large diameter parallel socketed, PVC fittings imported for either pressure or non-pressure applications may contain less than 1.5phr of TiO_2. However, these products are required to be Marked with the advice that "Protection required for use outdoors in direct sunlight".

Recommendations

Unless specified by the contract, regulation or similar, that AS/NZS2032 applies, it is recommended that:

a. PVC pipes and fittings made to the relevant AS/NZS Standards and containing not less than 1.5phr of TiO_2 be permitted to be stored outdoors for at least 2 years.

b. The PVC pressure pipes and fittings made to the relevant AS/NZS Standards and containing not less than 1.5phr of TiO_2 do not need to be painted unless painting is required for aesthetic reasons.

For Further information please contact
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