# Effects of UV Radiation on Building Materials

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**Abstract.** During recent years there has been increasing use of polymer-based materials, such as thermoplastics, thermosets and composites, as replacements for traditional building materials. Although these polymers offer an impressive range of attractive properties, the effect of climatic conditions on the durability and performance of these materials is not fully understood. This paper briefly examines the effects of UV radiation on the performance and properties of polymer-based building products.

## Introduction

The durability, performance and rate of deterioration of polymer-based products are all significantly influenced by both the material composition, and the climatic conditions to which they are exposed. To date, polymers have predominantly found applications in non-structural items, such as cladding, plumbing and coatings. That said, there is a continued increase in the use of polymeric materials, particularly polymer-based composites, for structural applications within the building industry. However, the weathering of thermoplastics, thermosets and composites, due to variations in temperatures, moisture/rainfall and UV radiation, is not fully understood. More understanding of the durability and weathering of these materials would enable the useful lifetime of building products to be predicted to a greater accuracy, as well as enable plans to be made for maintenance and replacement of key building components.

Current research at BRANZ continues to investigate whether climatic variations within New Zealand have a significant effect on the weathering and durability of building plastics. The main emphasis of the research is on the large variations in solar UV-radiation within New Zealand, and the resulting photodegradation reactions occurring from exposure at each of nine sites across the country.

## Polymer degradation

Most of the commercial organic-based polymers used in the building and construction industry undergo photolytic and photo-oxidative reactions during exposure to solar UV radiation. The polymers contain chromophoric groups, such as carbon-carbon double bonds (C=C) and carbonyl groups (C=O), which are capable of absorbing UV energy and are involved in the photo-reactions that result in the degradation of the polymer. These chromophoric groups can either exist within the regular structure of the polymer, or exist as a result of impurities present, or through thermal processing of the materials involved.

This is the situation with the polyolefins, polyethylene and polypropylene, which are severely affected by the presence of UV radiation. Although they have no carbonyl or C=C bonds within their regular structure, the chromophoric moieties are introduced into the backbone or side groups through the high temperature injection moulding and extrusion processes involved in producing the plastic building products. It is also understood that the metal-based additives contained within the polyolefins catalyse oxidation reactions resulting in photo-oxidative and thermo-oxidative degradation. Initiation of the photo-chemical degradation reactions can occur via free radical mechanisms, leading to the formation of hydroperoxides and chain scission, which eventually cause catastrophic failure of building components.

Degradation effects that occur within polymer-based materials range from discolouration on the polymer surface, which affects the aesthetic appeal of the material, through to extensive mechanical damage to the polymers, severely affecting the performance of the building product. The colour changes mainly occur as a consequence of chemical changes within the polymer structure, resulting in yellowing or darkening of the polymer.

The more serious effects of photo-degradation include micro-cracking and embrittlement of polymeric substrates. These effects are often accompanied by extensive deterioration in the mechanical properties of the materials, such as tensile strength, impact strength and elongation, all of which are important parameters in the performance of a building product.

It is therefore necessary to be able to predict the performance of building products in specific environments, particularly regarding the expected lifetime of materials. This research is beginning to yield data that will eventually allow a lifetime prediction for plastic materials based upon a knowledge of material formulation coupled with an understanding of climate within New Zealand.

## BRANZ Research

To begin the process of determining whether climatic variations within New Zealand had a significant effect on the weathering and durability of building plastics, BRANZ initially established four identical exposure sites across the country. These four sites were located at Kaitaia, Paraparaumu, BRANZ at Judgeford, and Invercargill. The plastic samples selected for the UV exposure study were all commonly used within the building and construction industry, including PVC, low density polyethylene and polypropylene sheets. Samples of the plastics have been exposed as non-stressed sheets, and an identical set of plastics have been set-up in an aluminium tension rig under a 1% strain to simulate the stress encountered by building plastics in certain situations. Two commercial plastic pipes

were also exposed on each of the sites, in addition to the plastics sheets.
In 2005 a further five sites were established to provide further detail on the effect of climatic variations within New Zealand. The five sites were chosen to fall between the sites already in operation and were located at Cromwell, Christchurch, Westport, Rotorua and Auckland. The types of plastic samples already exposed were duplicated onto each of these sites. Additional plastic materials were included at these sites and retrospectively added to the existing sites. These included clear acrylic, polycarbonate and polyester sheets as well as glass-filled composite sheets.

The research continues to measure changes in the mechanical, chemical and physical properties of each of the exposed sheets and plastic pipes. These properties are assessed at annual intervals.

The clear polypropylene samples have shown the most rapid decline in surface, colour and mechanical properties. By the end of three years of exposure the materials had undergone extensive micro-cracking and had lost all mechanical strength as shown in Figure 1.

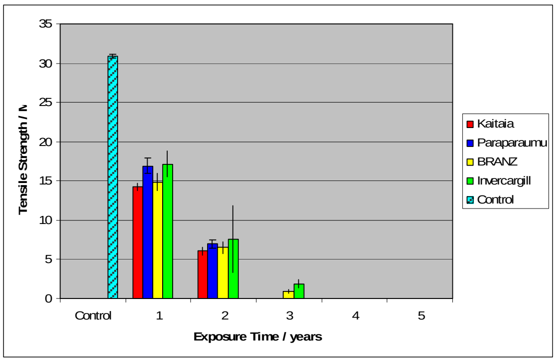


**Figure 1.** Clear polypropylene mechanical strength

The clear polyethylene samples have lost over 65% of their mechanical strength due to micro-cracking. Large shifts in colour have also occurred during the first four years of exposure. The clear polyethylene samples show increased material degradation at Kaitaia compared to the other sites. These results are shown in Figure 2.

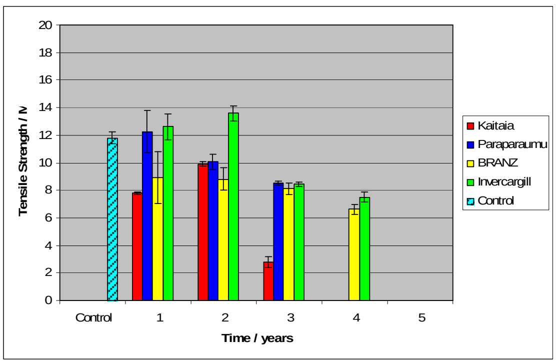


**Figure 2.** Clear polyethylene mechanical strength

In contrast, the black polyethylene samples have exhibited no change in material colour during the first four years of material exposure. The samples show a high density of very fine micro-cracks, but mechanical properties have been retained as the crack depth is very low in comparison to sheet thickness. This material contains carbon black which acts as a UV stabiliser and retards the photo-degradative effect of the solar UV radiation.

## Conclusions

The initial findings suggest that there are noticeable differences in the weathering of the different building plastics at each of the four established exposure sites. Although other climatic factors would have an effect on the results, the differing rates of degradation of the polymeric materials are believed to be due primarily to the variations in solar UV radiation between sites. Colour, gloss and analysis of the mechanical properties of the exposed plastics clearly indicate that the photo-oxidative degradation reactions are taking place at a quicker rate at Kaitaia than at any of the other sites. Overall, the results imply that items formed from clear polyolefin formulations will have a limited outdoor lifespan in any part of New Zealand, but that correctly formulated colour and stabiliser packages can upgrade material performance to deliver acceptable durability. It is envisaged that more trends will become evident as further analysis of existing samples is completed and as the plastics weathering project progresses over the next few years.

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## References

Addleson, L. and Rice, C. 1991. *Performance of Materials in Buildings.* Butterworth-Heinemann. Oxford, UK.

Davis, A. and Sims, S. 1983. *Weathering of Polymers*. Applied Science, London, UK.

Callaghan, S.J. 2001. 'Comparing Weathering of Plastics'. BUILD 43: March/April. BRANZ Ltd, Judgeford, New Zealand.

Gugumus, F. 1993. 'Re-evaluation of the stabilization mechanisms of various light stabilizer classes'. *Polymer Degradation and Stability* 39: 117.

Sharman, W.R. and Van Gosliga, N.L. 1989. 'Estimates of the Durability of Building Plastics and Rubbers in Exterior Applications'. *BRANZ Study Report No. 19*, BRANZ Ltd, Judgeford, New Zealand.