

EVALUATION OF THE PVC DEGRADATION USED IN BUILDING. MECHANICAL PROPERTIES.

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Abstract. *We have performed artificial accelerated ageing and a natural exposure in Campinas, SP, using PVC specimens cutted of walls used in building. The experimental results obtained permit us to compare the performance of PVC specimens submited to two different ageing methods. A dramatic decrese of elongation at break shows that this propertie is the most sensible for ageing evaluation.*

Keywords: *degradation, poly (vinyl chloride), natural and accelerated ageing, building applications and mechanical properties*

1. Introduction

Poly (vinyl chloride), PVC, materials are often chosen for many outdoor applications because of their excellent performance. However, the PVC resin by itself is not a weatherable material. It must be compounded and processed properly to achieve good long-term properties. The main factors influencing degradation of PVC materials include oxygen, humidity, mechanical stress, aggressive media and ionizing radiation, all being accelerated by increasing temperature. Degradation of PVC due to weathering is a free-radical mechanism started by the absorption of sufficient energy to break chemical bonds. Weak sites susceptible to degradation, as well as mechanisms of yellowing, oxidation, bleaching and surface erosion, have been investigated and described in several papers (Real and Gardette, 2001; Jakubowicz, 2001; Yarahmadi, Jakubowicz and Hjertberg, 2003). The effects of additives and impurities, which are always present in polymeric materials, on the degradation of materials exposed to ultraviolet (UV) light have also been described. The degradation leads to changes in initial properties as a result of chemical and physical processes, causing changes in chemical composition and material structure. One of these is dehydrochlorination, which is characterized by the formation of polyene sequences and thus discoloration of the polymer (Jakubowicz, 2001).

The low cost and good performance of poly (vinyl chloride) products have increased the utilization of this polymer in buildings, mainly in exterior applications, such as window profiles, cladding structures and siding. However, the ultimate user acceptance of the PVC products for outdoor building applications will depend on their ability to resist deterioration of their mechanical and aesthetic properties over long periods of exposure. To ensure the weatherability of these materials, the PVC resin needs to be compounded and processed properly, using suitable additives, leading to a complex material whose behavior and properties are quite different from the PVC resin by itself.

Although the basic mechanism of photo-degradation of PVC in now fairly well described in the literature, research concerning this subject has been carried out, in most cases, on carefully prepared solvent cast PVC films exposed to artificial light sources. However, there is no evidence that the results from these studies can be expanded, in their totality, so as to include extruded PVC compositions that are commonly used in outdoor building applications, especially in the cases that the composition include recently developed stabilizers. Furthermore, the outdoor degradation of such products is complex and is note yet completely understood for most of technical formulations, so the study of the photo-degradation of such products still remains a matter of interest (Real and Gardette, 2001).

Mechanical properties are frequently used as sensible and trustworthy criteria for determination of the technical quality of PVC materials. The most common measurements are tensile strength, elongation at break, modulus and impact strength. The effects of both physical and chemical ageing of PVC are generally reflected in its mechanical properties. Changes in elongation at break are the most sensitive measure of changes in the status of the material. This measurement, which is often neglected, is in many cases more important than the more common measurement as stress at yield. However, interpretation of the test results is very difficult owing to the large number of variables influencing mechanical properties. One of the important parameters is molecular weight. Especially at lower values, the mechanical strength increases as molecular weight increases. However, within the range typical for commercially used polymers, the influence is only slight. Many additives such as plasticizers, impact modifiers, processing aids, fillers, lubricants and stabilizers have a decisive importance for the mechanical properties of PVC. It is sometimes difficult to make unplasticized PVC flow smoothly through the processing equipment and produce homogeneous products. The morphology of the PVC resin particles is complex, and it can have a major effect on the degree of fusion and thus on the mechanical properties on the finished product. Furthermore, free volume, crystallinity and orientation are all important factors affecting physical and mechanical properties of PVC.

It is well established that conventional PVC is a partially crystalline polymer. In the amorphous state, polymer segments move by rotations around single bonds in the main chain of the polymer. The intensity of the motion increases with temperature. A segment moves in a concerted manner into holes adjacent to it and leaves at the same time a hole of similar dimensions behind. The local density on the molecular scale fluctuates to give an overall population of holes, which are often referred to as free volume. The glass transition temperature, *Tg*, is the temperature below which free rotations cease because of intramolecular energy barriers. Above *Tg*, the free volume reaches an equilibrium value, which depends on temperature but not on time. This state is frozen in by rapid cooling of the material from above Tg to below it, creating a no equilibrium state. The consequence is a slow structural relaxation process (physical ageing), which depends on the thermal history. Physical ageing as an inherent property of glassy materials has been studied extensively for many years. Knowledge about changes in mechanical properties due to ageing is important not only for the prediction of service life but also for the recycling of materials. The effect of additives and their interaction must also be considered owing to possible synergistic and antagonistic effects influencing various properties. (Yarahmadi, Jakubowicz and Hjertberg, 2003).

Inorganic and organic thermal stabilizers are commonly added to protect the polymer from heat degradation. Among the most widely used ultraviolet stabilizers is titanium dioxide pigment. Filling a polyvinyl chloride composition with this pigment substantially reduces the effective depth of penetration of ultraviolet light into the surface of an article formed from such a composition (Kamisli and Turan, 2005).

Natural and accelerate thermo-oxidative ageing are a common method for estimating the service lifetime of polymeric materials. In this study, PVC specimens was naturally aged (ASTM D1435) and accelerated aged (ASTM G53). Mechanical properties of initial and aged samples were evaluated.

2. Experimental

2.1. Material

The material studied was PVC used in external and internal walls of PVC houses. Specimens for tensile (ASTM D638) and impact (ASTM D256) tests were cut of external pieces. External surfaces had a thin layer of TiO_2. Figure 1 shows pieces of the wall system. The interior cavity walls in the houses are filled with a mixture of mortar and expanded polystyrene.

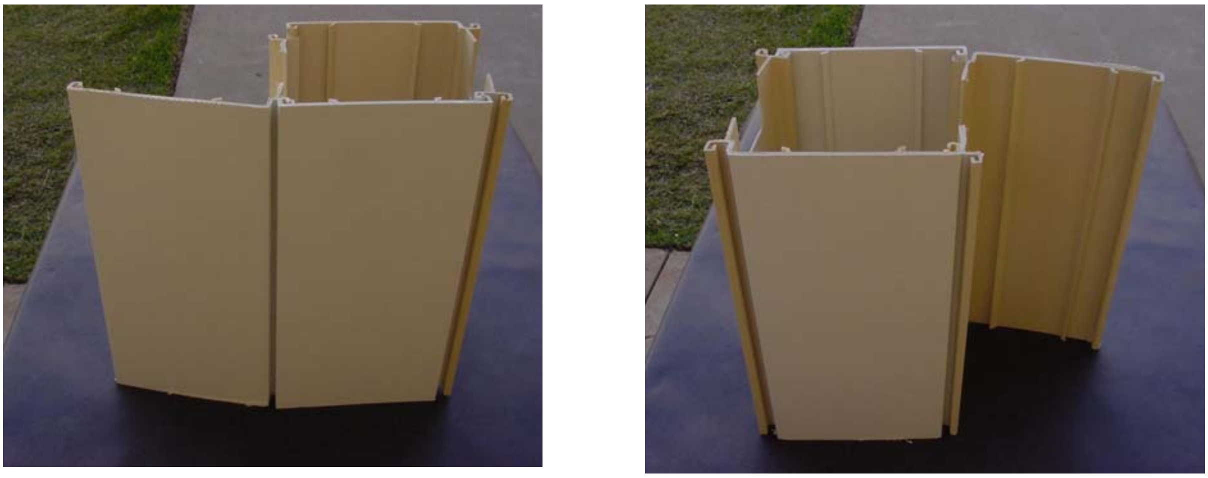

Figure 1. Pieces of PVC wall system.

2.2. Ageing

Accelerated ageing was performed according to the ASTM G53 standard in equipment with UV-A lamps, 22 h/d of exposition and 2 h/d of condensation cycles, for some periods.

Natural ageing was performed according to the ASTM D1435 standard, in Campinas, SP, Brazil during September 2004 to May 2005. UV radiation, air temperature, relative humidity and rain values were obtained by a Licor meteorological station. The material was exposed at 45° as well as horizontally, facing north.

2.3. Testing

Tensile properties were studied according to the ASTM D638 standard in a Tinius Olsen H5H-S machine, at 23 ± 2 °C and 50 % relative humidity and a test speed of 50 mm/min. Ten bars were tested per batch.

Impact resistance were evaluated according to the ASTM D256-02 standard, Izod method, in a pendulum impact Tinius Olsen 92T equipment, hammer of 2.7 J, with notched specimens, at 23 ± 2 °C and 50 % relative humidity. Ten bars were tested per batch.

Specimens of 0 h, initial material, 1 month and 3.5 months were evaluated. Specimens with more time were in ageing process.

3. Results and discussion

3.1. Natural weathering

The relative durability of PVC materials in different outdoor exposures can be very different on the variation in UV radiation, temperature, time of wetness, pollutants and other factors at various locations. Figures 2 to 4 summarize the meteorological dataset for the natural (ASTM D1435) exposition period of the specimens, in Campinas, SP.

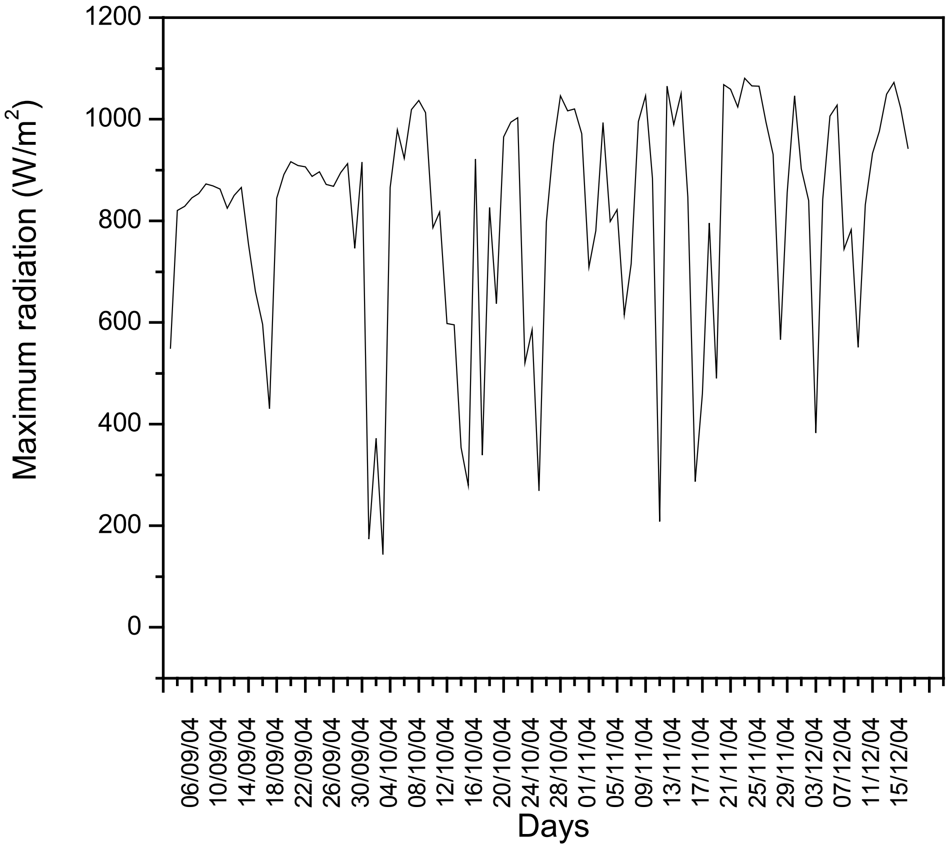

Figure 2. Example of variation of the highest radiation per day between September 2004 and December 2004.

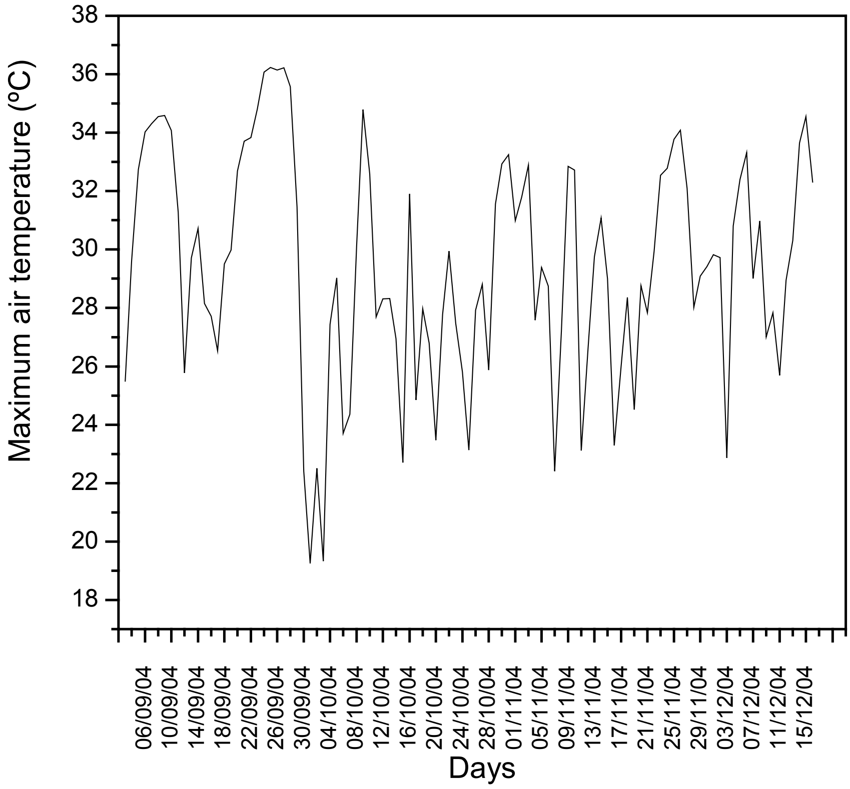

Figure 3. Example of variation of the highest air temperature per day between September 2004 and December 2004.

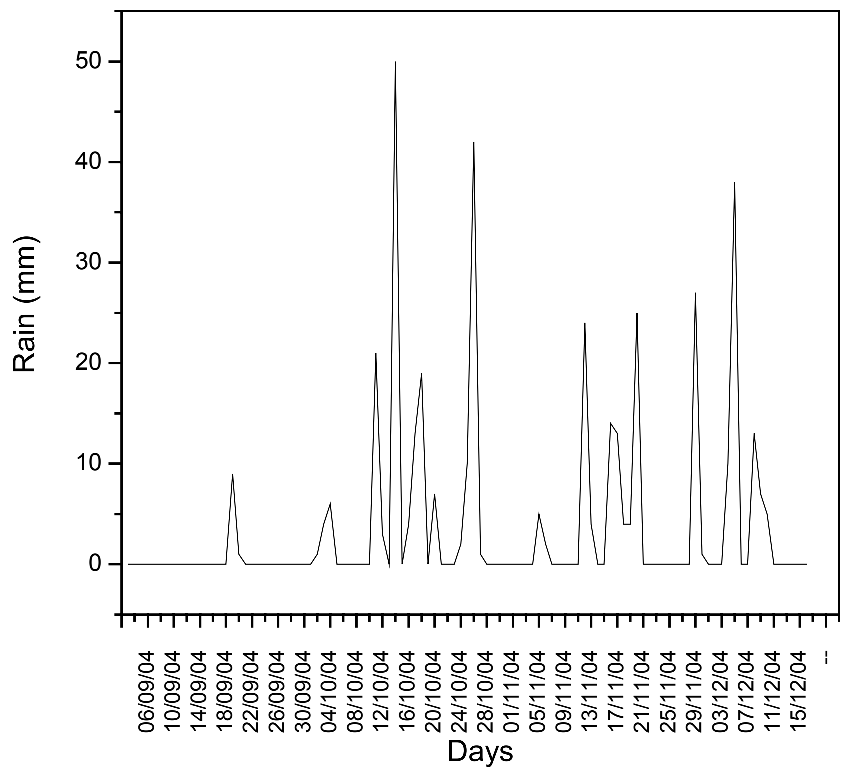

Figure 4. Example of variation of rain per day between September 2004 and December 2004.

3.2. Accelerated ageing

Figure 5 shows spectral range of UV-A lamps utilized for accelerated ageing (ASTM G53), and Figure 6 shows an example of temperature variation inside the apparatus for the period of specimens exposition.

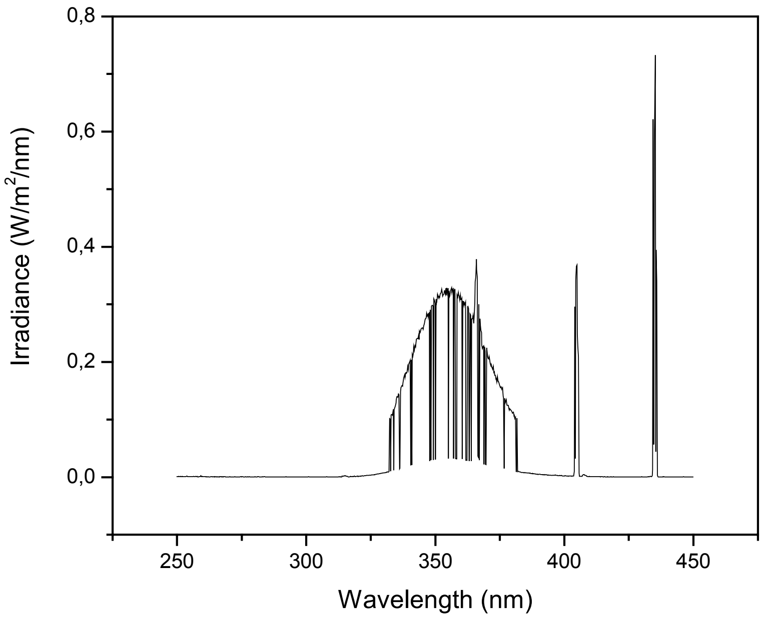

Figure 5. Spectral range of UV-A lamps in accelerated ageing.

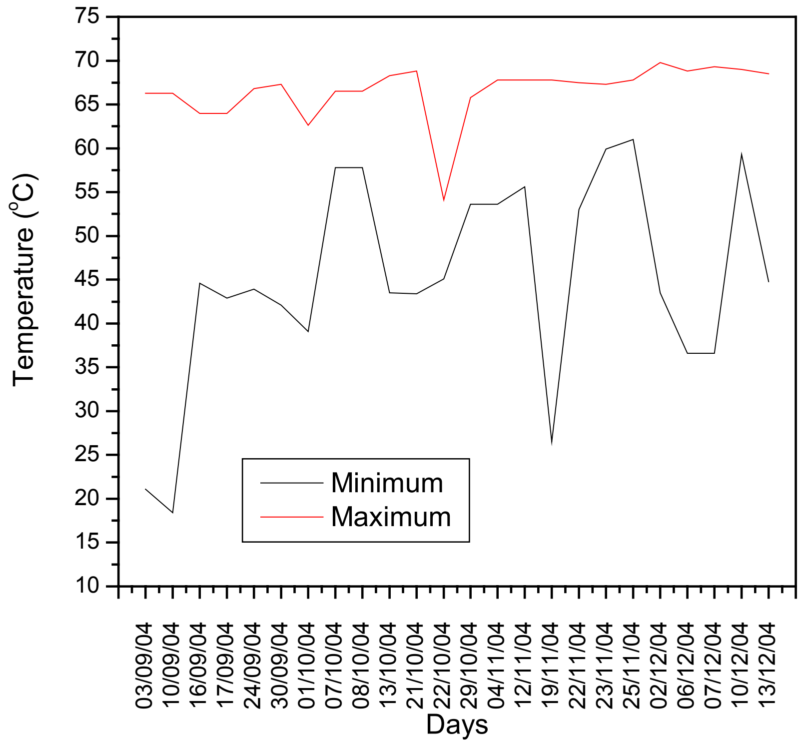

Figure 6. Example of variation of temperature in accelerated ageing apparatus.

3.3. Effects of ageing on impact strength

Figure 7 shows the impact strength in function of the ageing time for natural (ASTM D1435) and accelerated (ASTM G53) ageing.

Impact strength of natural aged specimens did not change for 3.5 months of exposure, but the accelerated ageing specimens showed a decrease with the increase of the ageing time. The break of all the specimens was a complete break.

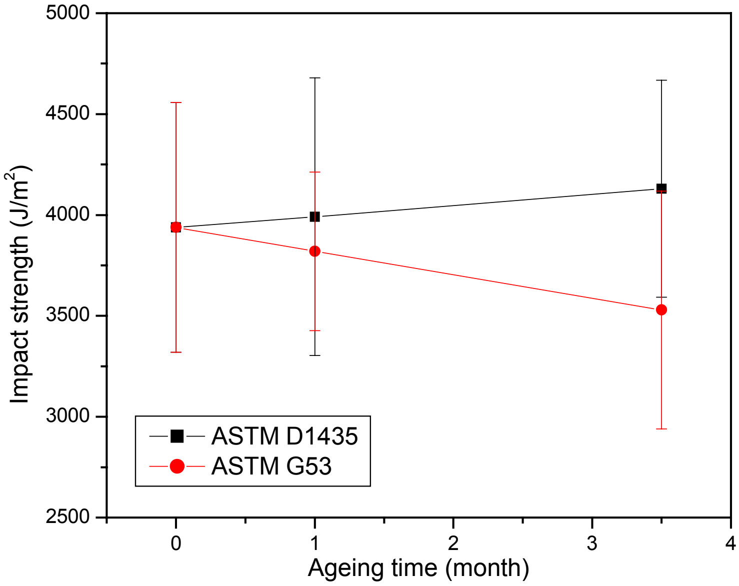

Figure 7. Impact strength as effect of ageing time for natural and accelerated methods.

3.4. Effects of ageing on tensile properties

The results of tensile tests corroborate that the elongation at break property had the most sensible behaviour (Fig. 8). This property dropped considerably with the increase of ageing time. The accelerated ageing showed a dramatic change after only one month of exposition. The behaviour of the elongation data shows that the surface degradation is very important, predominantly the surface layer that is degraded upon ageing. The degradation products act as stress raisers and lower the elongation at break values.

The elasticity modulus showed a little decay for both the ageing methods (Fig.9). Tensile strength increases with the ageing time for accelerated ageing, but didn't show an important variation for natural ageing. (Fig. 10). The increase of the tensile strength can be related to increase of the rigidity material by the ageing, resulted from physical ageing.

Accelerated tests were usually carried out because natural weathering tests may take many years to produce measurable degradation. Our results show that for PVC, only one month outdoor had sensible changes in tensile properties. In accelerated ageing we have to consider that the exposition was performed with higher temperature that natural method and with 22 h of irradiance per day.

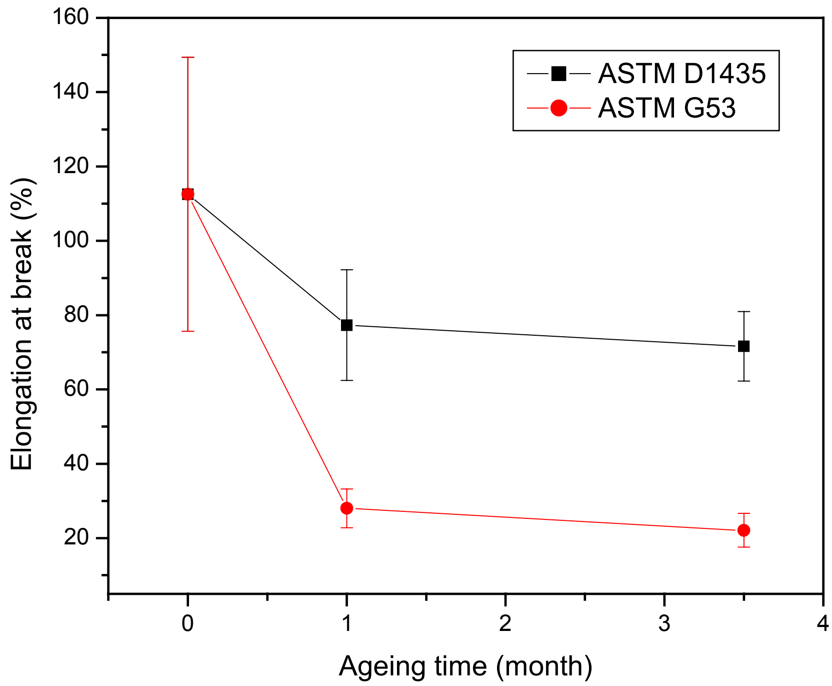

Figure 8. Elongation at break as effect of ageing time for natural and accelerated methods.

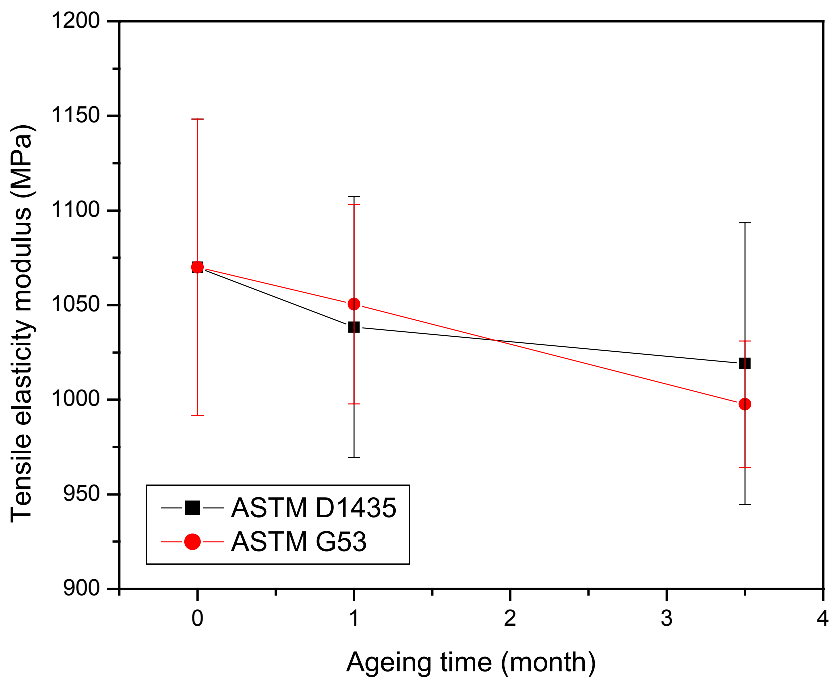

Figure 9. Tensile elasticity modulus as effect of ageing time for natural and accelerated methods.

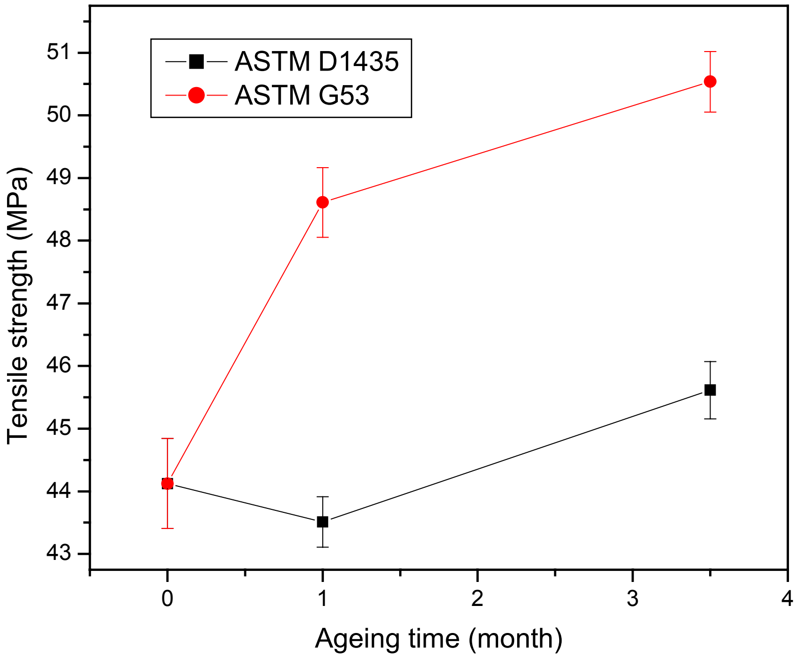

Figure 10. Tensile strength as effect of ageing time for natural and accelerated methods.

4. Conclusion

The elongation at break dropped on each ageing step and increased again upon each reprocess step. This behaviour suggests that the surface degradation is the major responsible for the drop of the elongation.

Tensile elasticity modulus was little affected in the processes in which the specimens of PVC were submitted; the elongation was the most sensible property for evaluation of the ageing.

Each property has an answer that can relate natural with accelerated ageing. We need more times of ageing to compare both methods.

5. References

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6. Responsibility notice

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