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# MECHANICAL PROPERTIES AND STRENGTH OF AGED PVC/CPE BLENDS

**Krisztina Roman*, Tibor Horvath, Dr. Tamas J. Szabo**
* Institute of Ceramics and Polymer Engineering, University of Miskolc, Hungary

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## ABSTRACT
The change of mechanical properties of PVC/CPE blend with different aging was studied. The relationships between the aging time and the properties were also investigated. Mechanical measurements assessed by tensile, flexural, impact tests. The results of tests showed that the PVC and CPE polymer make partially thermodynamically compatible systems. The differences between the original and aged samples occurred at the breaking elongation of the samples. The UV test was carried out on all samples (3 types). The result of the all mechanical and UV tests show that the strength of the aged sample decreases, although it is only a small change.

## INTRODUCTION
The PVC [poly (vinyl chloride)] is one of the most commonly used thermoplastic polymer in the world [1]. The most important area of the application is the industrial area. The PVC is characterized with good mechanical properties, light weight, weather resistance, excellent chemical resistance and geometrical stability [2]. Other than that, it has also disadvantages which are: thermal instability, occasional brittleness and difficulty to make compatible mixtures with other polymer [3]. For the application of PVC foam as insulations, it is necessary to improve the materials toughness [2-4].

PVC is often mixed with other polymers to enhance its properties [3]. The chlorinated polyethylene (CPE) is used in PVC as an impact modifier additive. The main reason for the mixing is to make thermodynamical miscibility between the two polymers [5]. The CPE has a positive effect in the properties of PVC mixtures, such as not migrating out of the structure, and being non-volatile material [6]. The other advantages are significant increase in the product's lifetime, reduction of the fragility, increase in the fire and impact resistance [7]. The CPE prevents the spreading of cracks. It is not a necessity to use expensive impact modifier additives; the CPE proves to be a cheap and good quality additive.

The thermal stability of PVC is poor without UV stabilizer. Due to the UV radiation, the product structure suffers degradation. These degradations are the photo- and photo oxidative-, thermal-, biological- and mechanical degradation. The sunlight can affect the molecular stability, therefore modifying the mechanical properties of the blends [8]. The average solar energy of Hungary is 1368.6 kWh/m$^2$, and the actual sunny hours are 2057 h/year [9]. In this paper, we have investigated five tests; UV-, hardness-, tensile-, impact-, three-point bending test.

## MATERIALS AND METHODS
The raw material was PVC powder (suspension grade PVC (K=56 values). The other additives of PVC composites were stabilizers, external and internal lubricants, ground $CaCO_3$ filler, foaming agent and the polymer additive. For the foaming process azodicarbonamid bowling agent was used. The content of the CPE was 8 phr in the blend.

### Sample preparation
PVC/CPE blends were prepared in high-speed dry mixer, the mixing temperature went up to 110°C. Twin-screw extruder was used for the production process. The barrel temperature was 165 to 180°C. From the mixtures foaming sheets were made, the final thicknesses of the sheets were 4 mm. The specimens were die cut from the sheets by pneumatic punching tool.

### Tensile test, flexural test and impact test
The tensile and flexural tests were made by INSTRON 5566 testing machine according to ASTM D638-10 and ISO 178:2010 standard. The tensile test cross-head speed was 200mm/min at 23°C room temperature. During the flexural test three-point bending head was used.

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The impact test was performed by CEAST 6545 testing machine. During the Charpy test 2J energy hammer was used according to EN ISO 179 standard. The radius of notch was 0.25 mm and the measurements were carried out at 23°C temperature.

**UV test**
The typical example of the degradation simulation is the UV test. The test was carried out with a homemade UV chamber. The device measured according to ISO 4892-3 standard. Power of UV camber is 32.4 W/cm$^2$. From the solar energy of Hungary, the actual number of sunny hours and the power of UV chamber the selected UV radiation time was calculated. This time – 1 hour – was equivalent to 486.96 natural hours, about 1.5 year.

## RESULTS AND DISCUSSION

**Tensile test, bending test and impact test**
During the tensile test, significant change was not observable in the strengths value in case of sample of equivalence with 1 year. The results of 3 years samples show more degradation of structure. Figure 1 shows the results of the stress-strain behaviors of the aged specimens.

***Table 1. Results of tensile test at different ageing time***

| Samples | Maximum tensile strength [MPa] | | |
|---|---|---|---|
| | Before ageing | Equivalent to 1 year | Equivalent to 3 years |
| PVC/CPE | 20.40 | 20.35 | 18.00 |

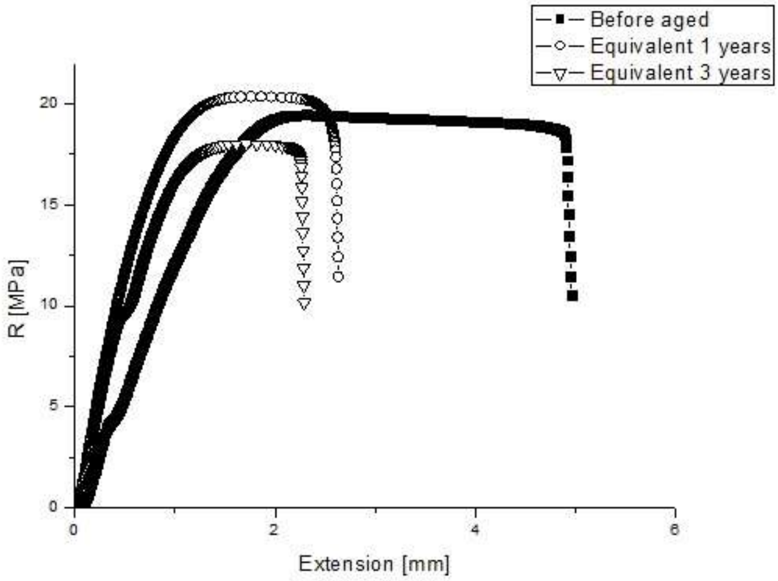


***Figure 1. Result of tensile test***

From the results of table 2 and 3 it can be seen, that it is similar to the tensile strength test results. Not even the 3 year equivalence of radiation was able break the molecule bonds and degrade the structure highly.

***Table 2. Results of impact test***

| Samples | Impact bending strength [kJ/m$^2$] | | |
|---|---|---|---|
| | Before ageing | Equivalent to 1year | Equivalent to 3 years |
| PVC/CPE | 2.61 | 2.44 | 2.35 |

***Table 3. Results of flexural test***

| Samples | Maximum flexural strength [MPa] | | |
|---|---|---|---|
| | Before ageing | Equivalent to 1year | Equivalent to 3 years |
| PVC/CPE | 32.11 | 29.72 | 29.55 |

***Table 4. Results of flexural test***

| Samples | Flexural modulus [MPa] | | |
|---|---|---|---|
| | Before ageing | Equivalent to 1 year | Equivalent to 3 years |
| PVC/CPE | 757.27 | 786.16 | 684,96 |

## CONCLUSION

In this paper the main concept was the ageing process and the aging effect of the blends. The original and the aged mechanical properties of the foam blends were measured. The results show that the CPE modified the PVC structure. The aging process works at equivalent to 1 and 3 years. All measurements have been performed on the original and the aged samples. During the mechanical tests the strengths values scarcely changed. The stress-strain diagram shows that the original sample has longer elongation than the aged samples. This means that the ageing effected the elongation ability of the material. In case of aged samples the break occurs sooner than in the original blend. According to the result, the aged blends have stable structure, and good mechanical properties similar to the original blend.

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