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# **The Effects of Accelerated Weathering on the Physical Properties of Aluminum Flake-Pigmented Materials**

**Written By:  
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# **The Effects of Accelerated Weathering on the Physical Properties of Aluminum Flake-Pigmented Materials**

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## **Abstract**

Aluminum flake products have been used in a variety of finished goods in the plastics industry. As the types of applications expand into outdoor use, more information has been desired regarding weathering and result integrity of these products. While it is accepted that aluminum flake (itself) is not greatly affected by weathering, much has not been discussed on the result physical properties of exposed materials that use these pigments.

This study focused on the use of several aluminum flake products, compounded with different polymers, and subjected to exposed and unexposed conditions. The variables included particle size, delivery form and types, concentration, UV stabilizer addition, and select polymers. ASTM Tensile and Charpy bars were molded for a variety of trials, with samples from each set exposed to accelerated weathering. After a specified time and condition set, all samples were tested for Charpy impact and tensile strength & elongation. Test results of exposed and unexposed samples were compared to determine basic trends of accelerated weathering on molded polymers.

The recorded data brings interesting information to light. In some of the observed cases, aluminum flake can be considered a means of protection from accelerated weathering conditions. As such, this feature potentially offers an additional value to this pigment.

## **Background Information**

In reference to the use of aluminum pigments, appearance and function are concerns as they are the primary reasons for using aluminum flake products. Changes in aesthetics can be examined by weathering exposure, via simulated or natural means, and determining color changes. Numerous studies have been performed for aluminum flake products used in paints. Likewise, studies have been produced for the effect of weathering on the color of molded parts. The data in these reports concern color shifts or film integrity. However, the effect of weathering on the physical properties of molded plastics that use aluminum pigments has not been widely examined or published.

A one theory has been proposed on the mechanisms and potential outcomes of these conditions. One suggests that the flake material will reflect light and prevent damage from occurring to the interior of the part<sup>1</sup>. Any breakdown of the polymer will occur only on the surface layers. This also suggests that the intermediate polymer may be affected twice, once upon entry and again on reflection.

For the purposes of simplicity, resource availability, and the sake of creating a straightforward basis for further endeavors, the choice of variables is narrowed. The materials involved are selected for reasons of handling, common usage, and range. Resources and equipment are limited to what is available and can be readily used. Training and techniques for the equipment used are basic and, at times, modified to keep the study simple and brief. Furthermore, the data seen offers a starting point for future study. Any of the variables used can be changed and selected based on the results observed here.

Aluminum flake products are manufactured in a variety of particle sizes and are categorized by their respective mean particle size D(50) measurement by laser-light scattering. A trend of this particle size is the inverse relation of size to opacity: the lower the D(50), the higher the opacity. This feature is examined in this study by selecting two flake types with distinct differences in size (14 micron and 45 micron). In theory, the smaller flake size should offer better coverage, and therefore, better protection.

In a related fashion, the loading level of aluminum products is examined. Concentrations of 1%, 3%, and 5% are made with each polymer type. These levels are selected as they are common in both aesthetic and functional applications. Through the variation of loading, the relation of concentration to the level of protection given can be observed.

The delivery form of the flake is also considered. Dry aluminum pigments and mineral spirits-based products are not recommended forms of addition to plastics processing, due to safety concerns. Solid carriers are studied due their ability to be used across a variety of resins, and a loading level respective to 3% aluminum flake is used. Two common carrier types in the industry (acrylic resin at 0.75%; and PE wax at 1.28%) are examined as both additive quality and through the incorporated aluminum flake product. Due to incompatibility, acrylic resin was not used for the trials involving polypropylene. Also, the use of liquid carriers was not investigated at this time due to some processing concerns.

A UV stabilizer is included into the study to determine its level of protection compared to the aluminum pigments, carriers, and unfilled resin. As with the carrier additives, the stabilizer is only used at one loading level (0.5%). The UV stabilizer is compounded in virgin resin and with the 14 micron flake type and carriers for each polymer in a separate series.

The selected field of polymers is narrowed to three common types used for outdoor products: polypropylene (PP), polycarbonate (PC), and acrylonitrile-butadiene-styrene (ABS). Polypropylene represents a polyolefin material; polycarbonate, as an engineering resin based on one monomer type; and ABS, as a copolymer (terpolymer) engineering resin. Each plastic is tested through filled and unfilled trials.

Finally, the weathering used will be accelerated by using UVB 313B light and 100% humidity cycles and modeled according to ASTM D4329. As the focus of this study is to identify basic & fundamental trends of weathering exposure on plastics, a shorter time frame is desirable – 100 hours of exposure under the established conditions. The UVB 313 lamps offer a destructive and accelerated exposure for the parts involved. Weathered samples are then compared to unexposed parts.

## **Experimental**

The experiment is divided into three sets according to polymer. All materials are compounded with the either PP, PC, or ABS according to the levels listed to Table 1 (below). For PP, no trials with acrylic resin were performed. Compounding is performed through a 1 1/4 inch single-screw extruder (25:1 LOD). The result compounds are molded into ASTM D6110/ISO 179 & ASTM D638 parts using a 55 ton injection molder.

Samples from each polymer experimental trial are tested for Charpy energy (J), tensile strength (MPa), and percent tensile elongation (ASTM D6110/ISO 179 & ASTM D638). These data become the base comparison for parts that have been exposed to the established accelerated weathering conditions.

Samples from each experimental trial are also mounted into a QUV test chamber. Conditions used are modeled from ASTM 4329 (8 hours UV @ 70C; then 4 hours no UV, 100% humidity @ 50C), UV 313B for 100 hours). After exposure, the parts are tested for Charpy energy (J), tensile strength (MPa), and percent tensile elongation. These data are compared to the respective results of unexposed trials.

Table 1

Trial Number	Grade	% Al Loading	% UV Stabilizer Loading
1	Clear polymer	0	0
2	Clear polymer, UV Stab.	0	0.5
3	Clear polymer, PE wax	0	0
4	Clear polymer, PE wax, UV Stab.	0	0.5
5	Clear polymer, acrylic resin	0	0
6	Clear polymer, acrylic, UV Stab.	0	0.5
7	14 micron Al flake, PE wax	1	0
8	14 micron Al flake, PE wax	3	0
9	14 micron Al flake, PE wax	5	0
10	45 micron Al flake, PE wax	1	0
11	45 micron Al flake, PE wax	3	0
12	45 micron Al flake, PE wax	5	0
13	14 micron Al flake, PE wax	1	0.5
14	14 micron Al flake, PE wax	3	0.5
15	14 micron Al flake, PE wax	5	0.5
16	14 micron Al flake, acrylic resin	1	0
17	14 micron Al flake, acrylic resin	3	0
18	14 micron Al flake, acrylic resin	5	0
19	45 micron Al flake, acrylic resin	1	0
20	45 micron Al flake, acrylic resin	3	0
21	45 micron Al flake, acrylic resin	5	0
22	14 micron Al flake, acrylic resin	1	0.5
23	14 micron Al flake, acrylic resin	3	0.5
24	14 micron Al flake, acrylic resin	5	0.5

## Results

### Polypropylene Trials:

Of particular note, the UV stabilizer does not detract from the properties to a large degree, if at all. Additionally, it appears to protect the properties of exposed parts in clear PP. The PE wax carrier offers a level of property retention for PP in exposed and unexposed cases (except tensile).

In the Charpy and Tensile testing, the aluminum flake products appear to offer a level of protection from the weathering exposure similar to the UV stabilizer addition. The protection is noticeable at the point of addition, and retention in pigmented parts is considerably higher than the clear polymer that has been exposed. Smaller particle sizes appear to protect the parts better than the larger flake sizes, supporting the idea that particle size plays a key role in weathering protection.

The tensile elongation of exposed pigmented parts is not retained like unexposed parts. However, the flake products offer some protection over that of clear polypropylene. UV stabilizer aids in protection; however, the stabilizer also modifies this property in the unexposed samples.

See Appendix 1 for graphical representation of the Polypropylene Trials results.

#### Polycarbonate Trials:

Referring to the effect of the additives on Charpy energy, the UV stabilizer, PE wax, and acrylic resin do not greatly affect the properties. The trend noticed is a slight decrease in Charpy energy. For tensile strength, the UV stabilizer, PE wax, and acrylic resin also do not greatly affect the properties. The trend noticed is a slight increase in strength, with exposed PC showing a decrease. For tensile elongation, the PE wax and acrylic resin have a noticeable affect on the properties. Both carrier types create allow less elongation in exposed samples. It is only through the addition of UV stabilizer that elongation is seen comparable to unexposed parts.

In the Charpy testing, the UV stabilizer creates a decrease in impact energy in both exposed and unexposed samples (seen previously<sup>2</sup>). The aluminum flake products do not offer much protection from exposure, as decreases are observed from that of the clear PC. The limited protection is noticeable at the point of addition, and increased addition levels create less property retention. Larger particle sizes appear to offer better property retention in exposed and unexposed samples, regardless of carrier or exposure. The relation of particle size and protection is not established in this polymer trial.

For tensile strength, the UV stabilizer addition increases this value in both carrier types and exposure sets. In exposed and unexposed cases, aluminum flake offers a fair amount of protection in PE wax trials, and a considerable amount in acrylic tests. Particle size appears to be factor again, with smaller sizes yielding higher strength values.

Tensile elongation trials show a distinct trend of property loss with all additions and in both exposure sets. The observed effects are apparent at the point of product and/or additive addition. .

See Appendix 2 for graphical representation of the Polycarbonate Trials results.

#### ABS Trials:

For all additions of UV stabilizer and carriers, there is a decrease in Charpy, tensile strength, and elongation. The trend is consistent with both exposure sets. Elongation shows the largest change.

In the Charpy tests of aluminum flake addition, all sets of unexposed parts yield a decrease in impact energy with increased loading. The same trend continues when UV Stabilizer is added. Most exposed samples with aluminum products show property retention over unfilled samples, which increases slightly with higher pigment loading. Only in lower loading does UV stabilizer offer more retention in exposed samples.

For tensile strength, unexposed samples containing aluminum pigment and/or UV stabilizer show little change in property value. Exposed samples that use these additions possess much more retention compared to that of exposed clear ABS. This trend also shows that smaller particle size and pigment concentration contribute to this benefit. At higher loadings, the strength rivals that of unexposed trials, regardless of stabilizer addition.

Tensile elongation tests show a decrease in value in exposed samples. However, this trend reverses during exposure, and the properties increase when small particle size and higher concentration are used. UV stabilizer offers more protection from exposure only at lower pigment concentrations.

See Appendix 3 for graphical representation of the ABS Trials results.

## Summary

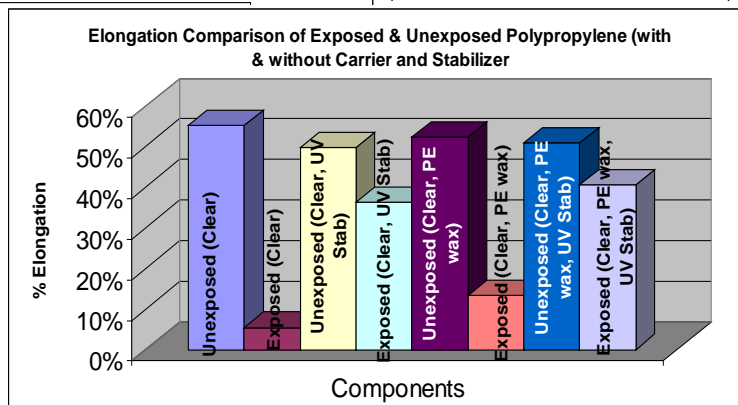
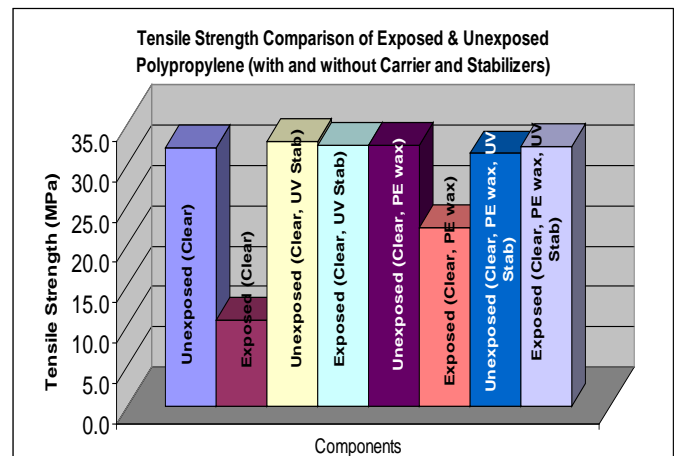
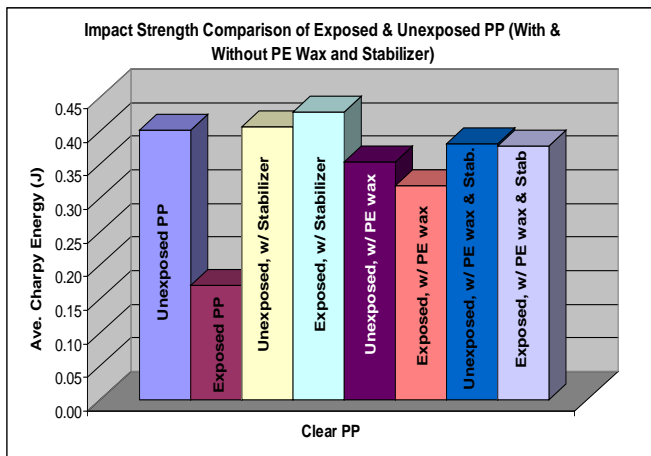
Through the observations of this experiment, aluminum flake products can offer weathering protection to injection molded parts to varying degrees. The amount of protection, however, is dependant on polymer type, additives, flake size, and loading. Mechanisms for the effects and results outlined in this report have not been fully determined as of yet. Support for some of the proposed theory is observed, and a set of trends is seen in most cases. Overall, aluminum flake products can be offered as a value-added pigment in select cases. Through careful testing and formulation, the use of stabilizer additives may be reduced or eliminated, potentially saving material, labor, and sourcing costs.

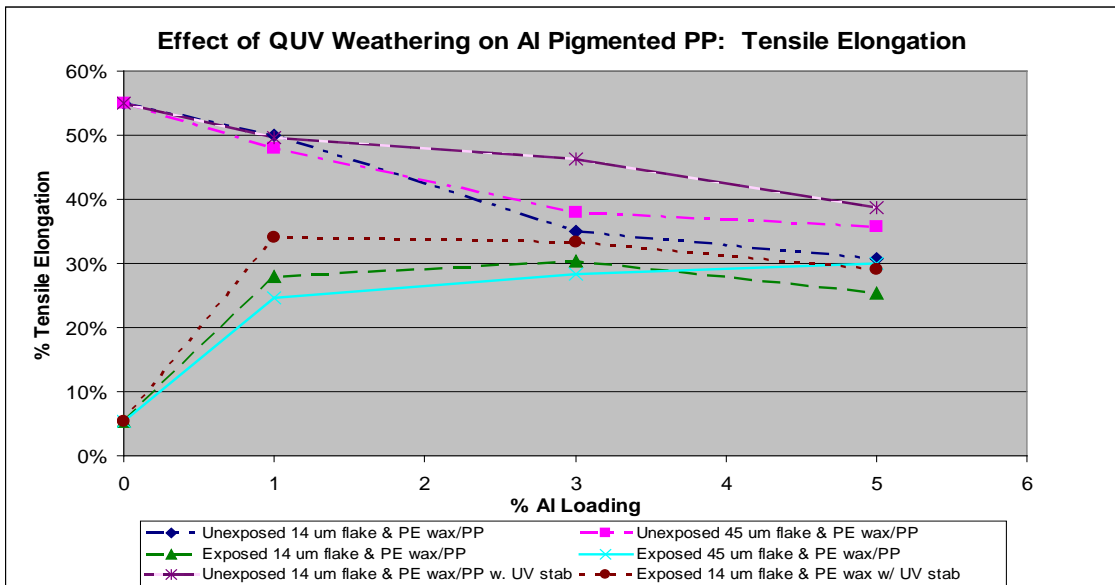
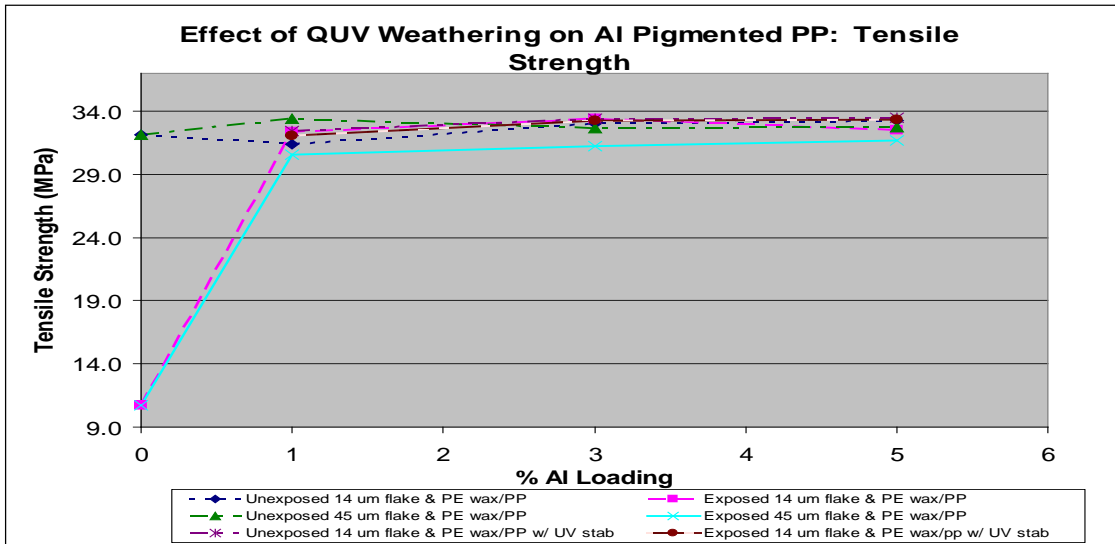
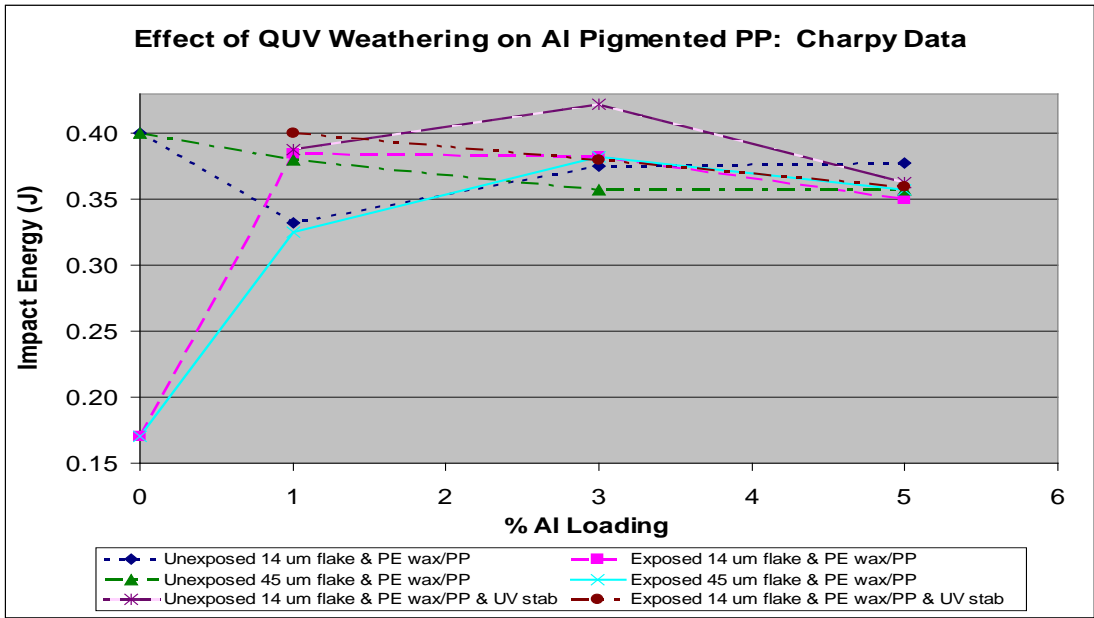
## References

<sup>1</sup>Ian Wheeler, *Metallic Pigments in Polymers*, Rapra Technology, Ltd., Shawbury, Shrewsbury, Shropshire, United Kingdom SY4 4NR, 1999, p. 199.

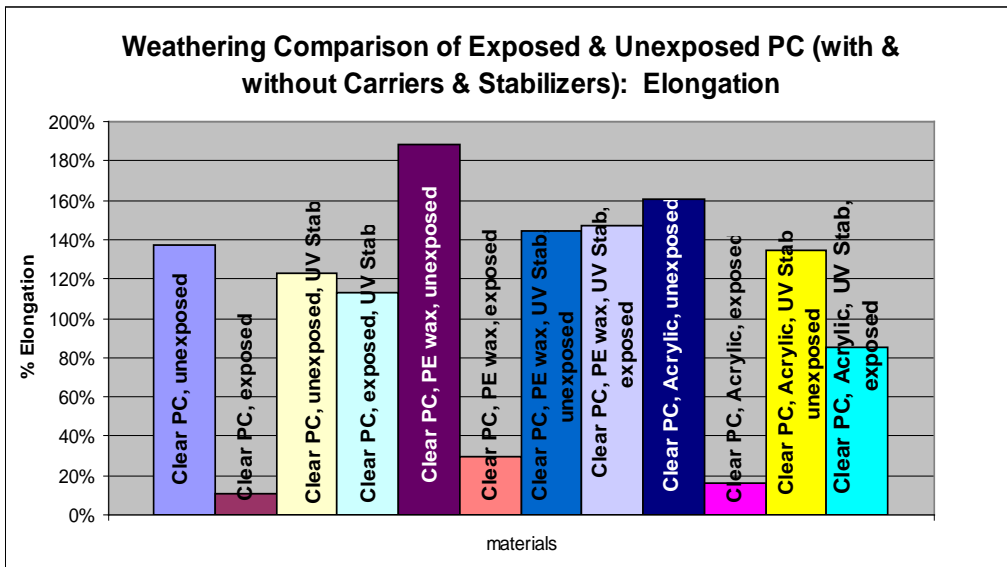
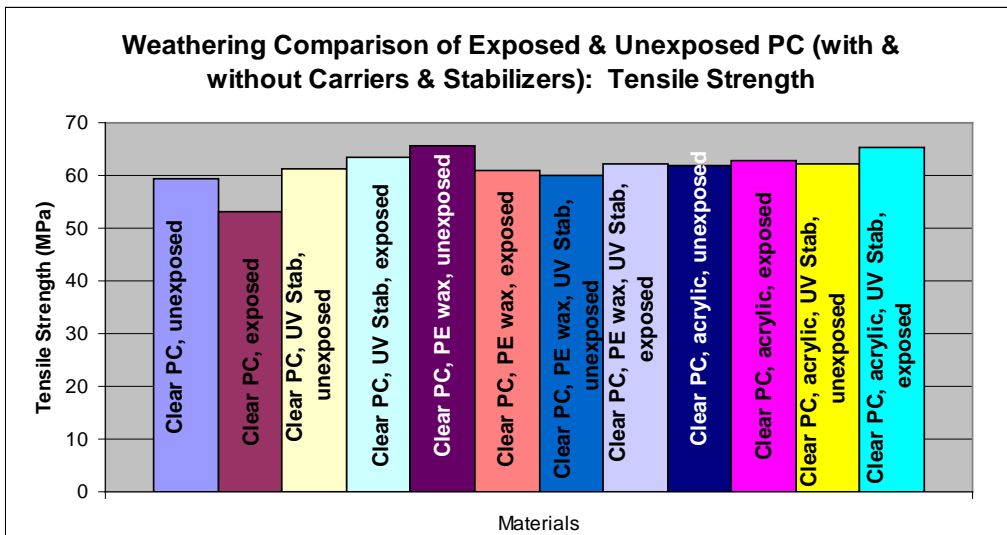
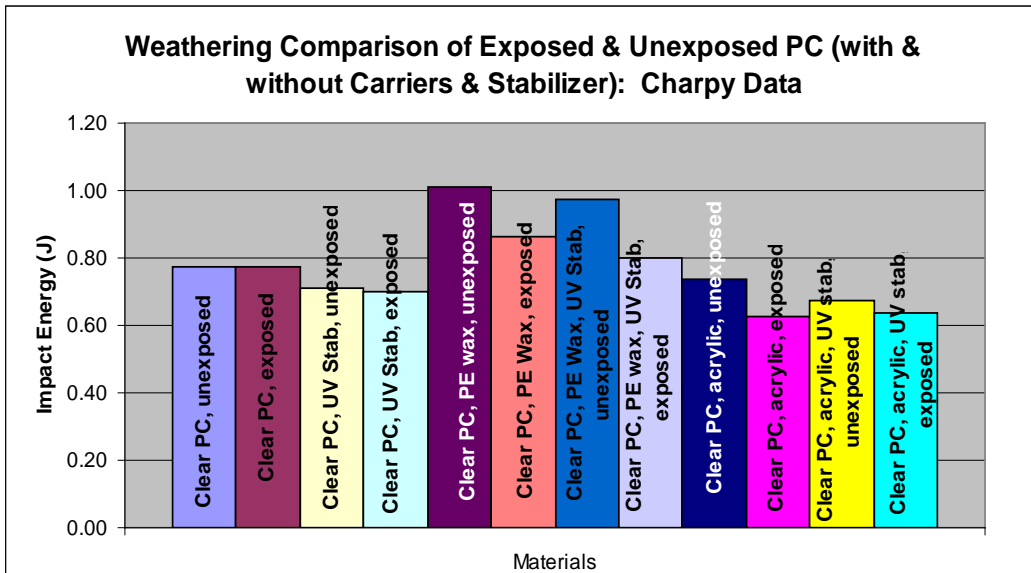
<sup>2</sup>Mike Sanchez, *The Effects of Metallic Pigment Dispersions On Physical Properties of Engineering Thermoplastics*, RETEC - Color and Appearance Division of SPE, Charlotte, NC, September 2005.

## Appendix 1 - Polypropylene Trials

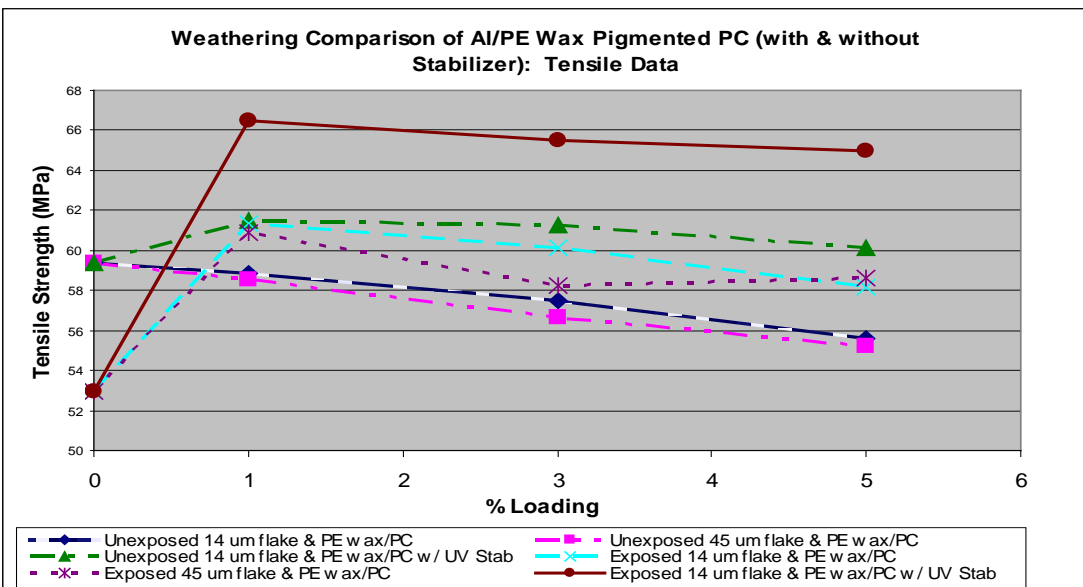
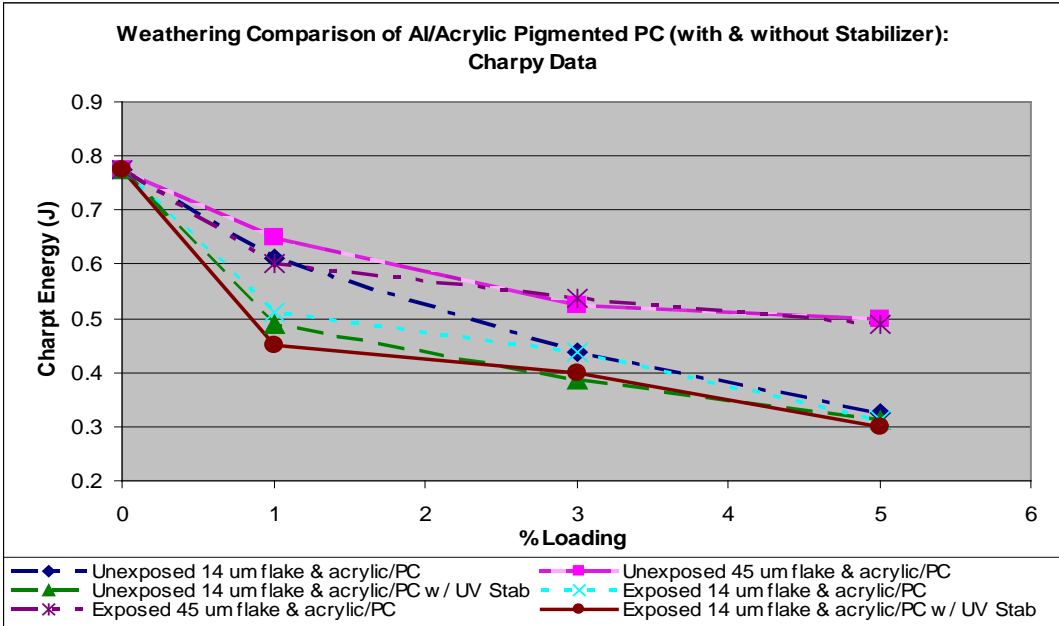
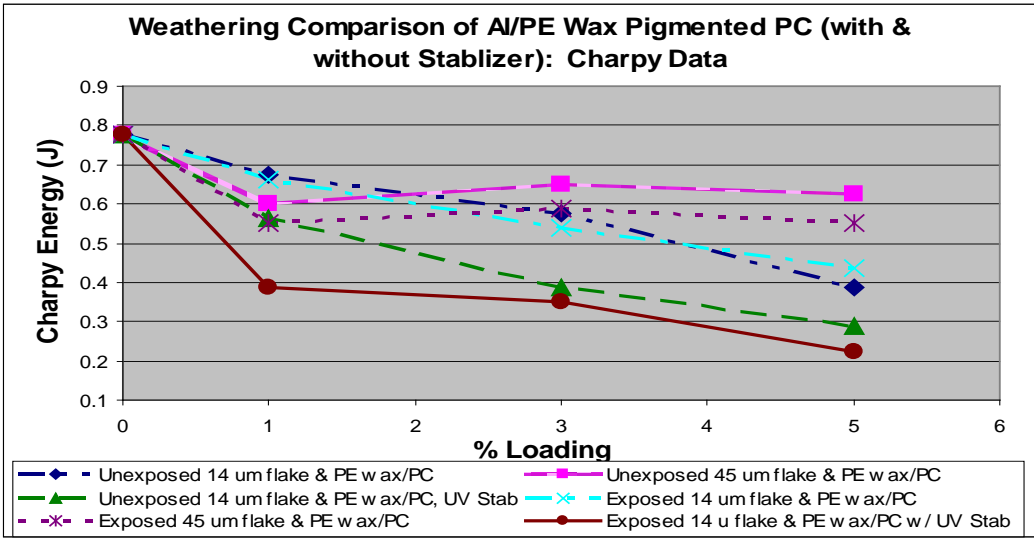


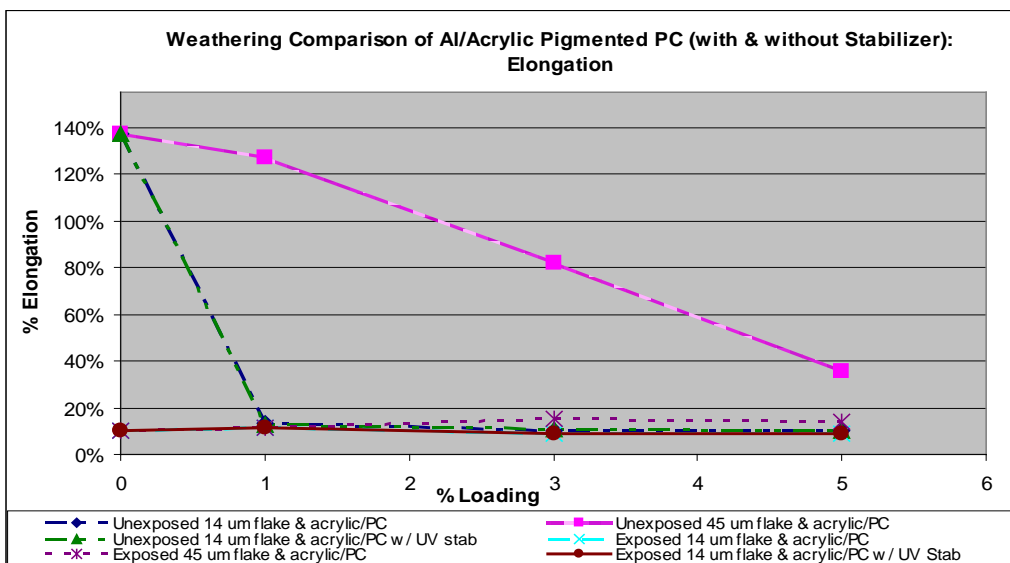
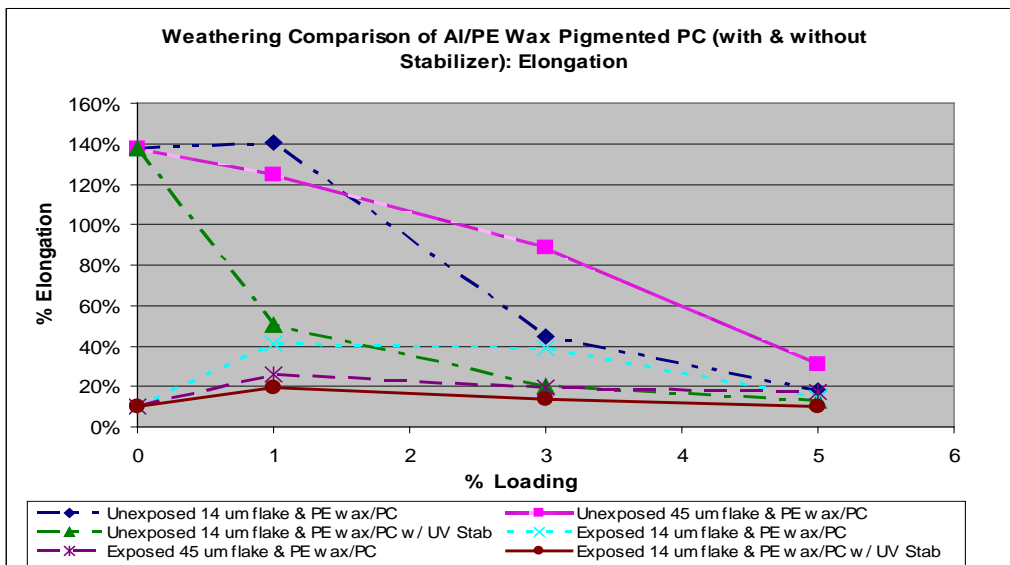
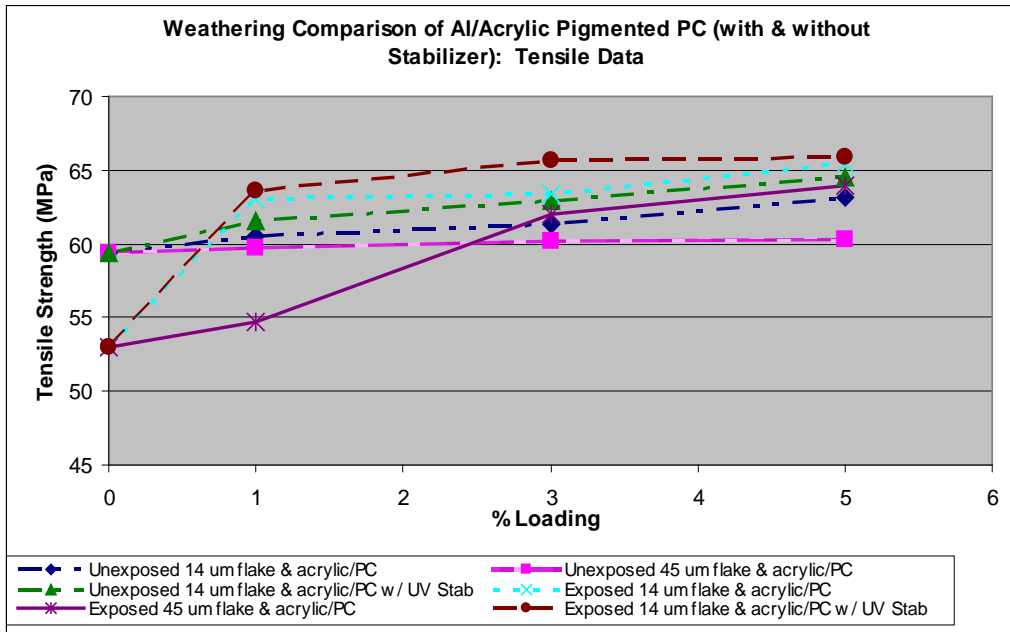


## Appendix 2 – Polycarbonate Trials

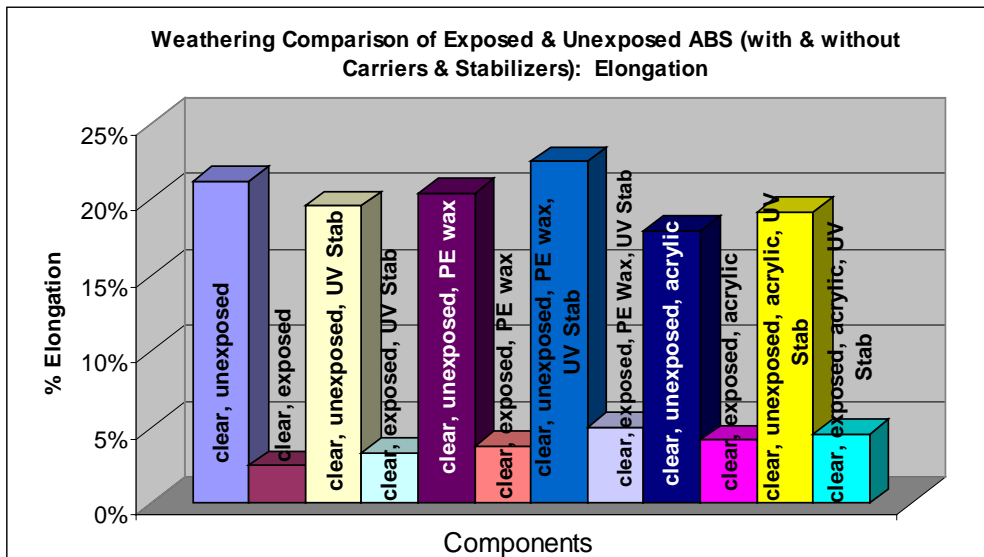
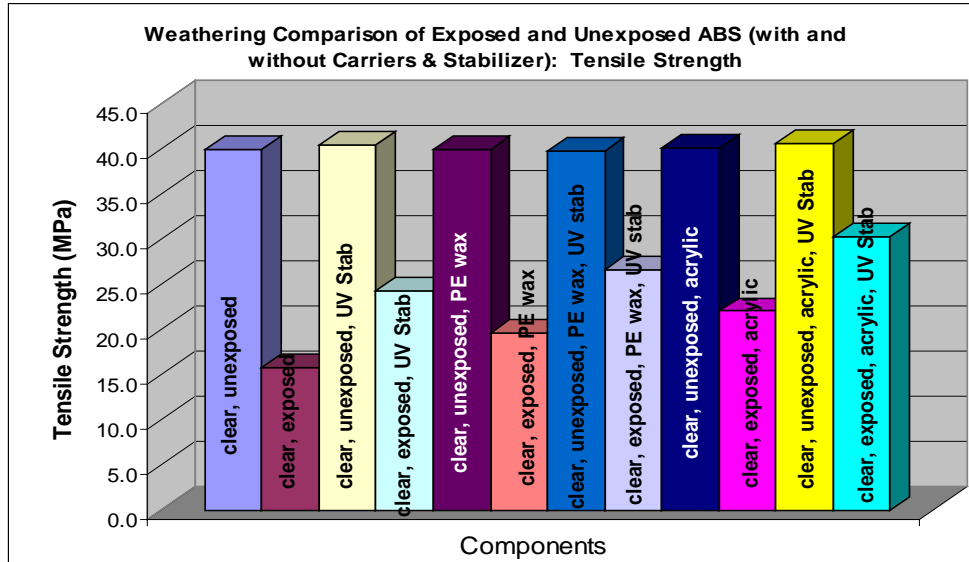
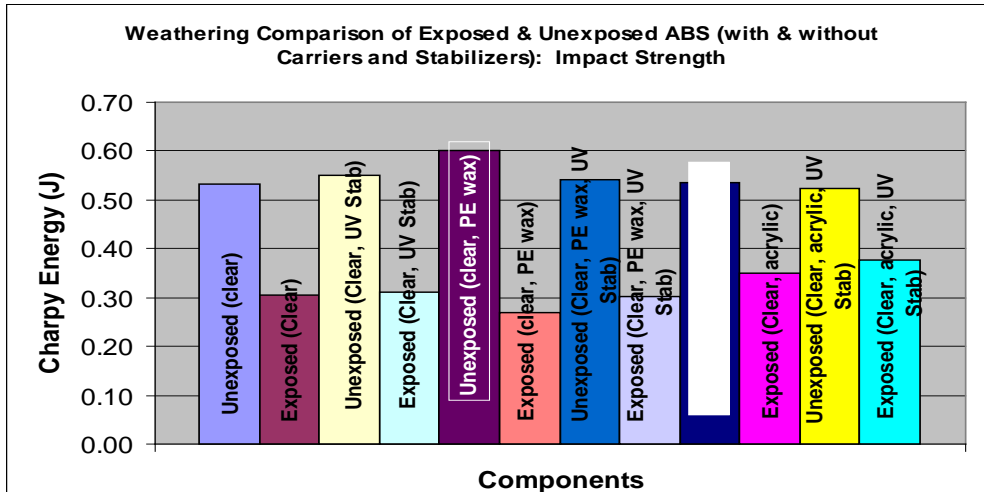


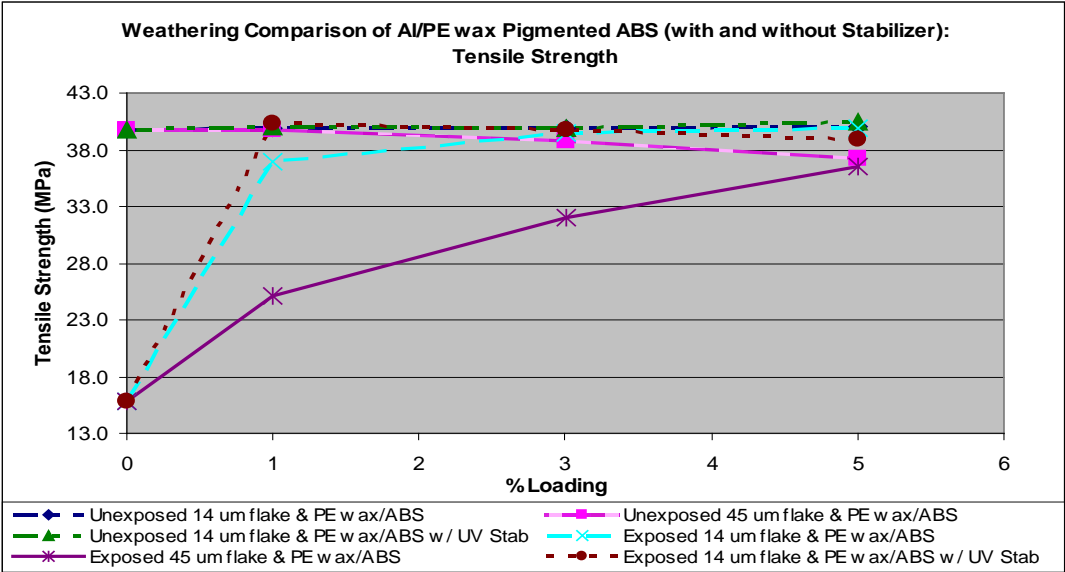
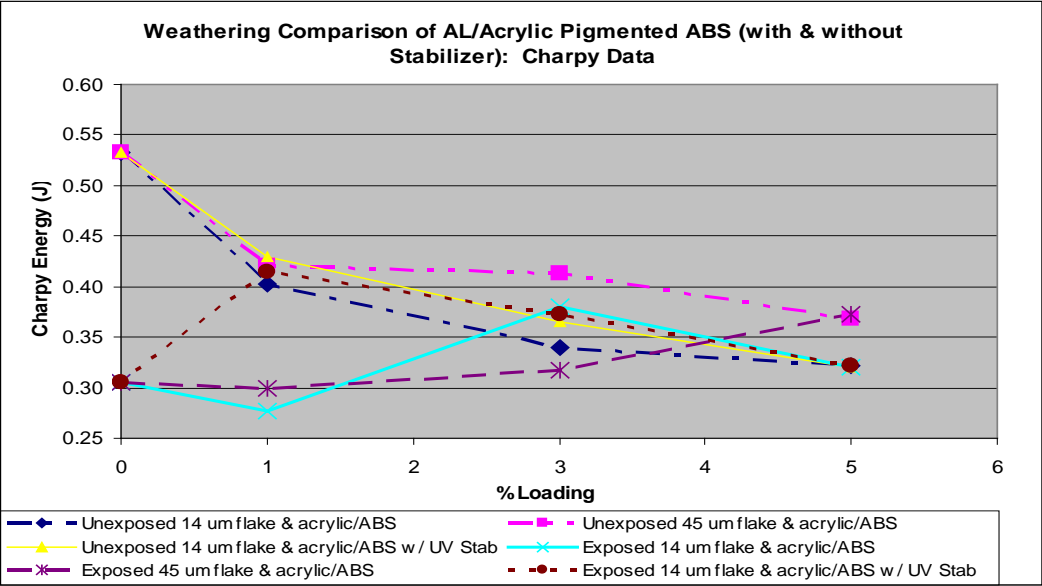
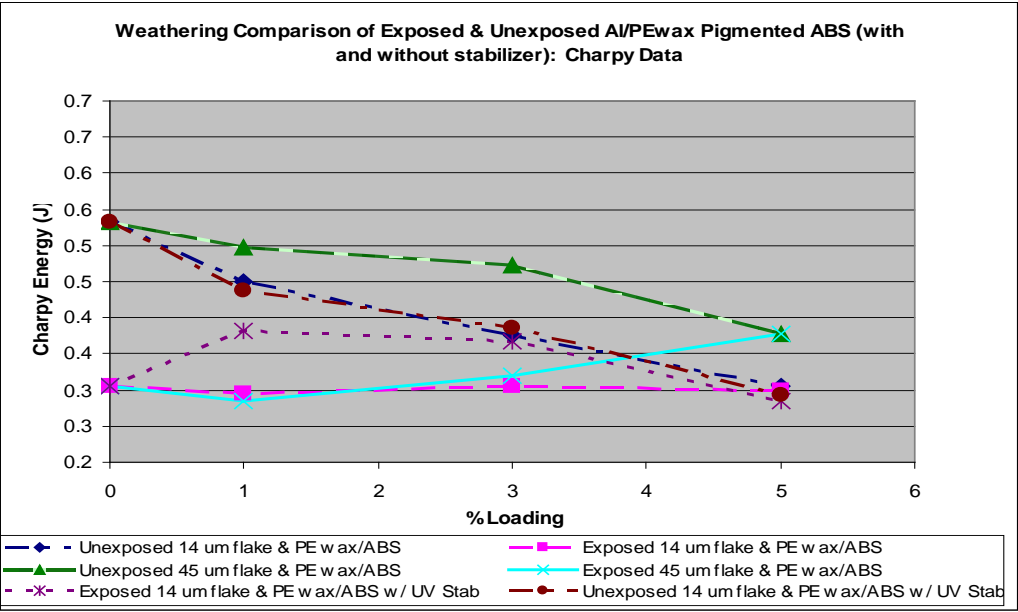


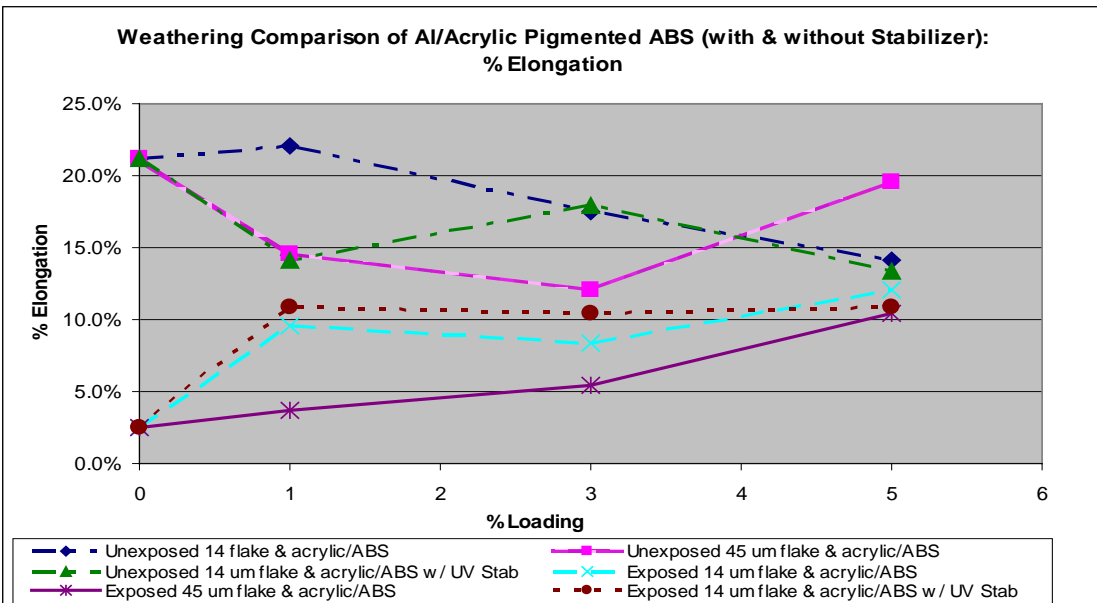
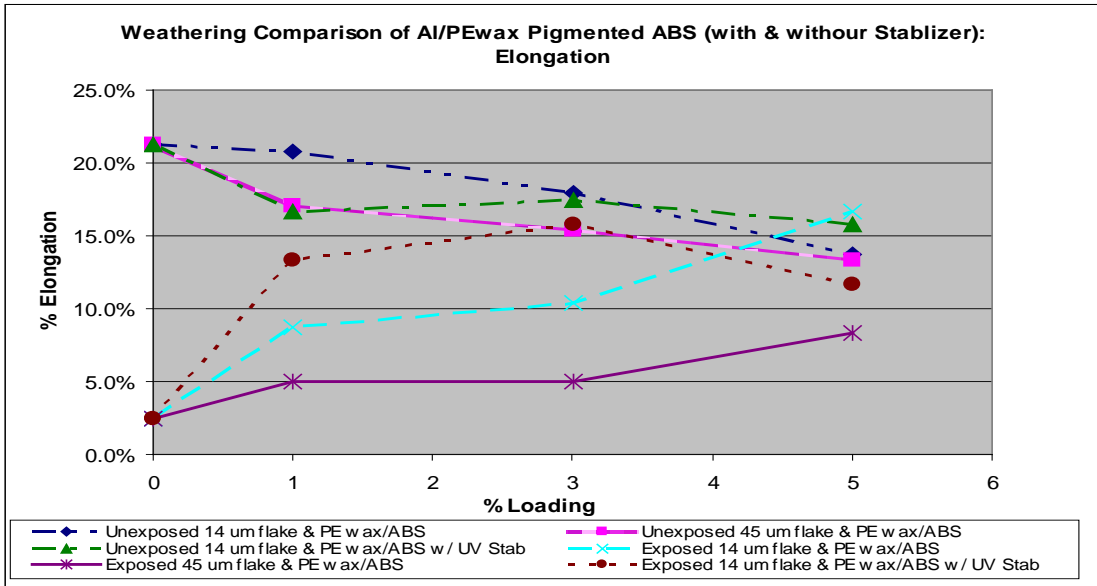
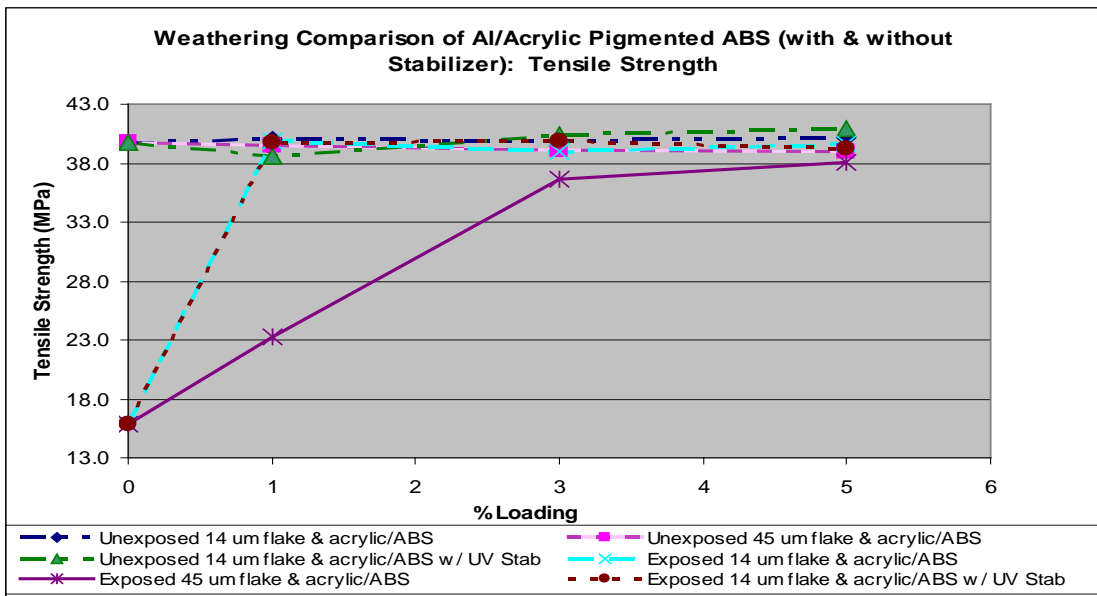




# Appendix 3 - ABS Trials







# The Effects of Accelerated Weathering on the Physical Properties of Aluminum Flake-Pigmented Materials



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