T.E.I. of Larissa
Karditsa Branch

Department of Wood & Furniture Design and Technology

**TECHNICAL REPORT:**

# DETERMINATION OF COLOUR CHANGES ON COATED WOOD SAMPLES AFTER NATURAL WEATHERING

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# 1. INTRODUCTION

This technical report contains the results of natural aging measurements (according to European Norm EN927-3) on wood samples covered with 6 different protective systems.
For the completion of the project the following researchers worked: **Dr. George Mantanis** – Professor, **Dr. Charalampos Lykidis** and **Dr. Dimitrios Birbilis** – Researchers (project at TEI Larissa, Research Committee, Project no. 3775).

# 2. MATERIALS AND METHODS

For the conduction of the research the European Norm 927-3 was applied. 48 pinewood (*Pinus nigra*) specimens free of infections, cracks, resinous streaks, knots and other defects were prepared. In more detail, the samples had dimensions of 24x7,8x2cm (total surface=0,05m$^2$) and were carefully prepared in order to have a growth ring inclination between 5-45° towards the samples face. The samples were conditioned at constant climate of θ=20±2°C and RH=65±5% and were sanded with a mesh 150 sand paper just before coating.
The coatings applied were 5 different Sayerlack and 1 Adler water-based systems for outdoor use. In addition to the above, specimens without any coating and ICP (Internal Comparison Product) specimens according to EN927-3 were also prepared for comparison.
The specimen treatments of the experiment are shown on Table 1.
The Sayerlack coating systems were applied by Sayerlack technicians and all other coatings were carried out by the research team. The preparation of all specimens was carried out in the Laboratory of Wood Technology, Department of Wood and Furniture Design and Technology at Karditsa, Greece.
All unexposed surfaces of the above specimens were covered with a Sayerlack polyurethane sealer type 218/13, 400/00 (2:1) according to the instructions of the Sayerlack technicians. The samples were then conditioned to constant weight at θ=20±2°C and RH=65±5% and weighed in order to determine the coating rate of all coating systems (coating weight/total specimen surface).
Afterwards, the samples were securely placed on a frame (according to EN927-3) located on the ceiling of the department of Wood and Furniture Design and Technology (Fig. 1) and the natural aging of the samples was carried out by exposing them to natural weather conditions for 12 months.
Eight measurements of color and weight were carried out during the natural aging. The measurements were carried out after 0, 16, 55, 82, 115, 152, 219 and 362 weathering days. Prior to every measurement the samples were conditioned in a climate chamber at temperature of 20±2°C and air relative humidity of 65±5% for 24-48h in order to minimize implications of water on the specimen color.

*Table 1: Coating systems used in the research*

| Coating Name | Coating System | No of specimens |
|---|---|---|
| Sayerlack 1 | AM303/89<br>AM603/91<br>AZ9030/86 | 6 |
| Sayerlack 2 | AM549/51<br>AZ2131/85 | 6 |
| Sayerlack 3 | AM549/51<br>AM475/00<br>AZ9730/85 | 6 |
| Sayerlack 4 | AM508/00<br>AM610/00<br>AZ8130/00 | 6 |
| Sayerlack 5 | AM508/07<br>AM490/00<br>AZ3230/85 | 6 |
| Adler Ligno | 57960 Aquawood Ligno+ Base<br>59110 Aquawood Ligno+ Sealer<br>59111 Aquawood Ligno+ Top | 6 |
| blank | none | 6 |
| ICP<br>(Internal Comparison Product) | Sayerlack polyurethane sealer<br>218/13, 400/00 2:1 | 6 |

Subsequently, all specimens were weighed and used for the determination of the color coordinates and other surface changes such as checks, mould growth or other macroscopically detected changes. The determination of the color coordinates was carried out using a Lovibond® CAM-System 500 camera-based imaging colorimeter (Fig. 2).

Color determination was carried out on the whole exposed surface of the specimens. Applying the CIELAB color system, the color parameters L* (Lightness), a* (redness) and b* (yellowness) were determined. For each of the specimens and for each weathering sub-period the total color changes (ΔE*) were calculated using the following equation:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Where:

ΔL*, Δa* and Δb*: The changes of the color coordinates L*, a* and b*

*Figure 1: The samples placed in a frame located on open air (note: other specimens are also placed on the frame)*

*Figure 2: Lovibond®CAM-System 500*

For each coating system a mean value of the parameters L*, a*, b* and ΔE was calculated using the determined measurements.
The relative changes of all color coordinates were also determined using the formula below:

$$\text{Change}(\%) = \frac{(\text{value after weathering interval} - \text{value prior to weathering interval})}{\text{value prior to weathering interval}} \times 100$$

Throughout the weathering period, air temperature and air relative humidity data were collected by a weather station located in the city of Karditsa (http://www.meteokar.gr).

# 3. RESULTS

## 3.1 Results prior to weathering

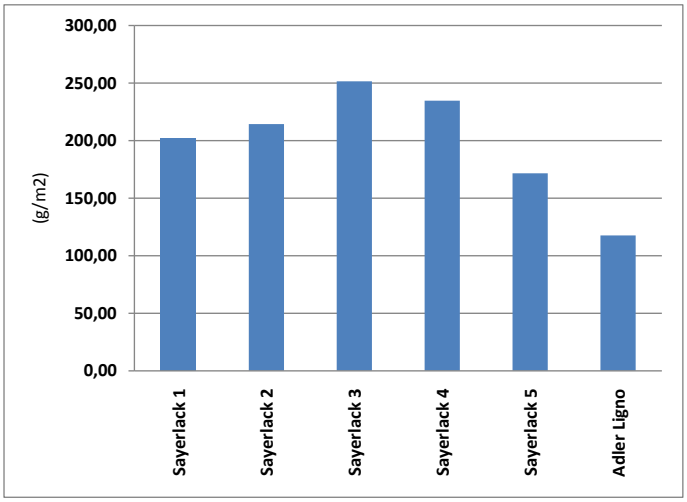
### 3.1.1 Mass changes

*Table 2: Coating parameters of all specimens*

| No | Coating type | Specimen | Initial mass (g) | Mass with coating (g) | Coating system mass (g) | Mass per area (g/m2) |
|---|---|---|---|---|---|---|
| 1 | Sayerlack 1 | 1 | 226,74 | 237,51 | 10,77 | 215 |
| | | 2 | 285,05 | 292,39 | 7,34 | 146 |
| | | 3 | 284,76 | 296,29 | 11,53 | 230 |
| | | 4 | 285,93 | 296,51 | 10,58 | 211 |
| | | 5 | 234,85 | 245,97 | 11,12 | 222 |
| | | 6 | 220,88 | 230,31 | 9,43 | 188 |
| 2 | Sayerlack 2 | 1 | 285,20 | 296,56 | 11,36 | 226 |
| | | 2 | 276,40 | 286,17 | 9,77 | 195 |
| | | 3 | 222,47 | 233,71 | 11,24 | 224 |
| | | 4 | 233,26 | 244,99 | 11,73 | 234 |
| | | 5 | 288,40 | 297,72 | 9,32 | 186 |
| | | 6 | 223,83 | 234,95 | 11,12 | 222 |
| 3 | Sayerlack 3 | 1 | 258,94 | 272,44 | 13,50 | 269 |
| | | 2 | 216,53 | 229,05 | 12,52 | 250 |
| | | 3 | 296,64 | 310,63 | 13,99 | 279 |
| | | 4 | 208,97 | 221,05 | 12,08 | 241 |
| | | 5 | 267,98 | 279,50 | 11,52 | 230 |
| | | 6 | 216,30 | 228,39 | 12,09 | 241 |
| 4 | Sayerlack 4 | 1 | 226,40 | 239,89 | 13,49 | 269 |
| | | 2 | 285,15 | 295,42 | 10,27 | 205 |
| | | 3 | 266,50 | 277,81 | 11,31 | 225 |
| | | 4 | 274,52 | 286,65 | 12,13 | 242 |
| | | 5 | 231,61 | 243,19 | 11,58 | 231 |
| | | 6 | 223,47 | 235,37 | 11,90 | 237 |
| 5 | Sayerlack 5 | 1 | 232,15 | 240,62 | 8,47 | 169 |
| | | 2 | 282,13 | 289,77 | 7,64 | 152 |
| | | 3 | 224,36 | 236,16 | 11,80 | 235 |
| | | 4 | 284,01 | 291,65 | 7,64 | 152 |
| | | 5 | 214,05 | 223,00 | 8,95 | 178 |
| | | 6 | 290,36 | 297,52 | 7,16 | 143 |
| 6 | Adler Ligno | 1 | 216,71 | 223,48 | 6,77 | 135 |
| | | 2 | 279,94 | 286,22 | 6,28 | 125 |
| | | 3 | 264,05 | 270,49 | 6,44 | 128 |
| | | 4 | 237,90 | 243,46 | 5,56 | 111 |
| | | 5 | 233,07 | 238,15 | 5,08 | 101 |
| | | 6 | 277,13 | 282,37 | 5,24 | 104 |

*Table 3: Descriptive statistics of coating parameters*

| | | Specimen | Initial mass (g) | Mass with coating (g) | Coating mass (g) | Mass per area (g/m2) |
|---|---|---|---|---|---|---|
| 1 | Sayerlack 1 | Average | 256,37 | 266,50 | 10,13 | 201,92 |
| | | St. Dev. | 31,95 | 31,72 | 1,54 | 30,66 |
| | | Max | 285,93 | 296,51 | 11,53 | 229,86 |
| | | Min | 220,88 | 230,31 | 7,34 | 146,33 |
| 2 | Sayerlack 2 | Average | 254,93 | 265,68 | 10,76 | 214,45 |
| | | St. Dev. | 31,58 | 30,97 | 0,97 | 19,36 |
| | | Max | 288,40 | 297,72 | 11,73 | 233,85 |
| | | Min | 222,47 | 233,71 | 9,32 | 185,81 |
| 3 | Sayerlack 3 | Average | 244,23 | 256,84 | 12,62 | 251,53 |
| | | St. Dev. | 35,55 | 36,09 | 0,94 | 18,79 |
| | | Max | 296,64 | 310,63 | 13,99 | 278,91 |
| | | Min | 208,97 | 221,05 | 11,52 | 229,67 |
| 4 | Sayerlack 4 | Average | 251,28 | 263,06 | 11,78 | 234,85 |
| | | St. Dev. | 27,20 | 26,53 | 1,06 | 21,10 |
| | | Max | 285,15 | 295,42 | 13,49 | 268,94 |
| | | Min | 223,47 | 235,37 | 10,27 | 204,74 |
| 5 | Sayerlack 5 | Average | 254,51 | 263,12 | 8,61 | 171,65 |
| | | St. Dev. | 34,54 | 33,32 | 1,69 | 33,71 |
| | | Max | 290,36 | 297,52 | 11,80 | 235,25 |
| | | Min | 214,05 | 223,00 | 7,16 | 142,74 |
| 6 | Adler Ligno | Average | 251,47 | 257,36 | 5,90 | 117,52 |
| | | St. Dev. | 25,92 | 25,85 | 0,70 | 13,86 |
| | | Max | 279,94 | 286,22 | 6,77 | 134,97 |
| | | Min | 216,71 | 223,48 | 5,08 | 101,28 |



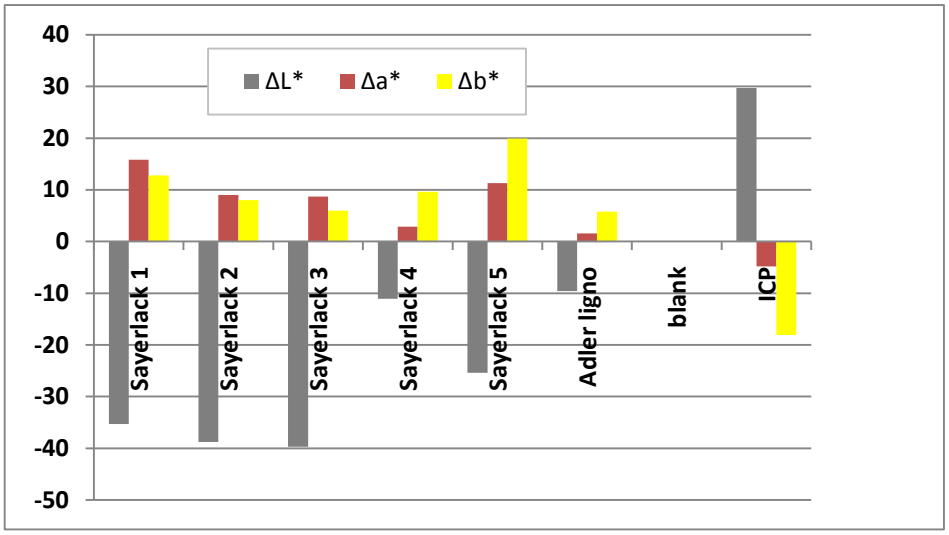

*Graph 1: Coating system rates for the coating systems applied in this research*

From Table 3 and Graph 1 it can be concluded that coating rate of ingo specimens was less (by almost 50%) than all Sayerlack ones.

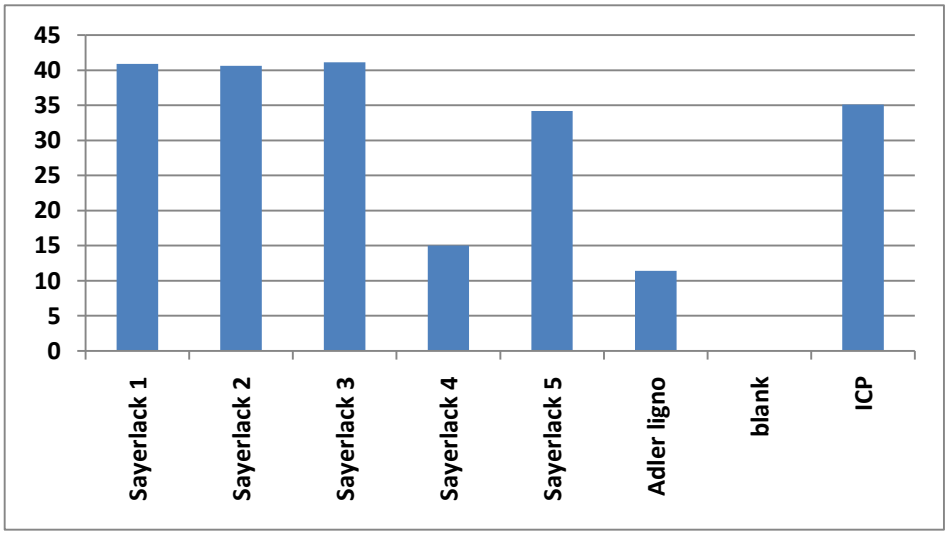
### 3.1.2 Color changes

*Table 4: Color changes occurred due to the coating of the specimens (prior to weathering)*

| | | ΔL* | Δa* | Δb* | ΔE* |
|---|---|---|---|---|---|
| 1 | Sayerlack 1 | -35,3 | 15,8 | 12,8 | 40,9 |
| 2 | Sayerlack 2 | -38,8 | 9,0 | 8,0 | 40,6 |
| 3 | Sayerlack 3 | -39,7 | 8,7 | 6,0 | 41,1 |
| 4 | Sayerlack 4 | -11,1 | 2,9 | 9,6 | 15,0 |
| 5 | Sayerlack 5 | -25,4 | 11,3 | 19,9 | 34,2 |
| 6 | Adler ligno | -9,6 | 1,6 | 5,8 | 11,4 |
| 7 | blank | 0,0 | 0,0 | 0,0 | 0,0 |
| 8 | ICP | 29,7 | -4,8 | -18,1 | 35,1 |




*Graph 2: Changes of individual color coordinates due to the coating of the specimens (prior to weathering)*




*Graph 3: Total color changes (ΔE* values) occurred due to the coating of the specimens (prior to weathering)*

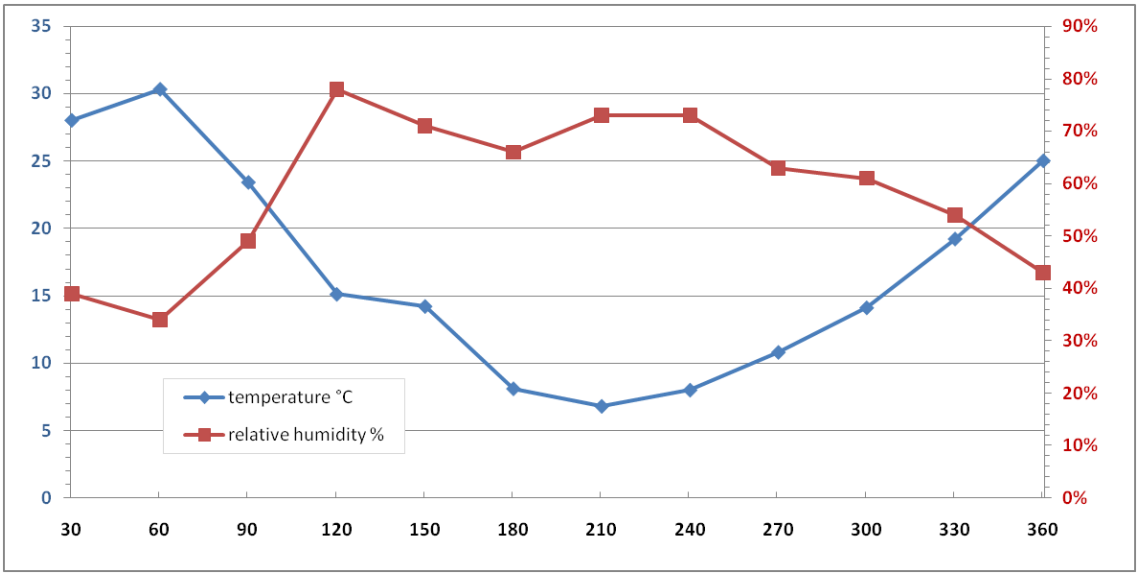
From *Table 4*, *Graph 2* and *Graph 3* it can be concluded that Adler ingo coating resulted to milder color changes of the specimens. Among Sayerlack coated specimens, Sayerlack 1-2-3 coating systems resulted to the largest color changes of the specimens.

## 3.2 Results after natural weathering

### 3.2.1 Weather changes

*Table 5: Measured weather parameters during weathering*

| Weathering Month | Month | Mean Temperature (°C) | Mean Relative Humidity (%) |
|---|---|---|---|
| 1 | July 2010 | 28,0 | 39 |
| 2 | August 2010 | 30,3 | 34 |
| 3 | September 2010 | 23,4 | 49 |
| 4 | October 2010 | 15,1 | 78 |
| 5 | November 2010 | 14,2 | 71 |
| 6 | December 2010 | 8,1 | 66 |
| 7 | January 2011 | 6,8 | 73 |
| 8 | February-11 | 8,0 | 73 |
| 9 | March 2011 | 10,8 | 63 |
| 10 | April 2011 | 14,1 | 61 |
| 11 | May 2011 | 19,2 | 54 |
| 12 | June 2011 | 25,0 | 43 |

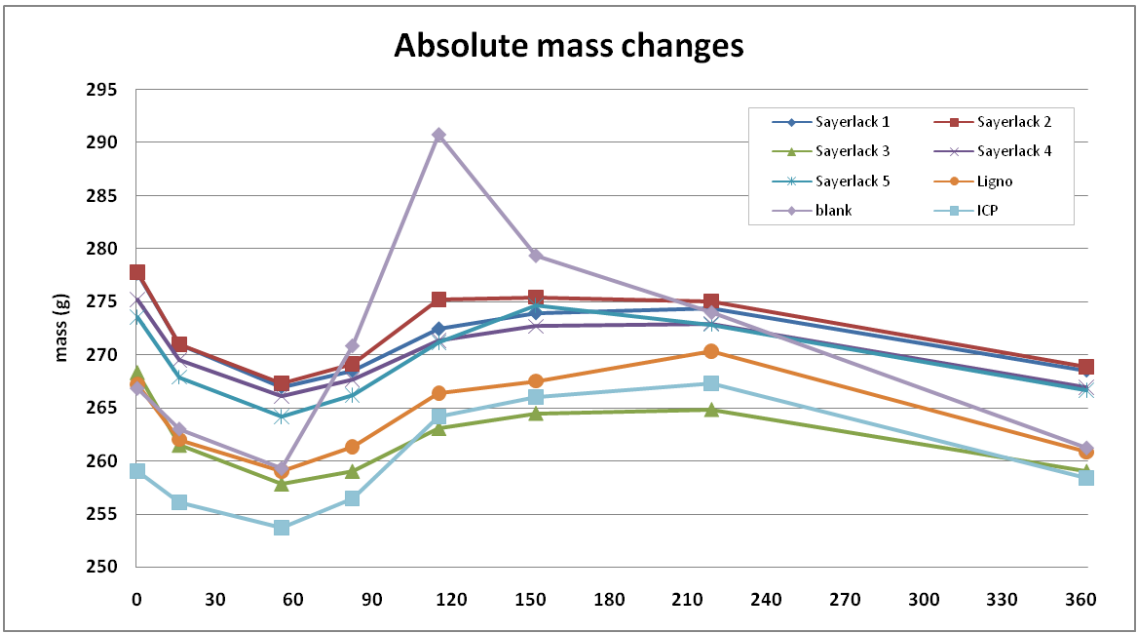



*Graph 4: Weather parameters: mean temperature (blue line) and mean relative humidity (red line) corresponding to the days among measurements*

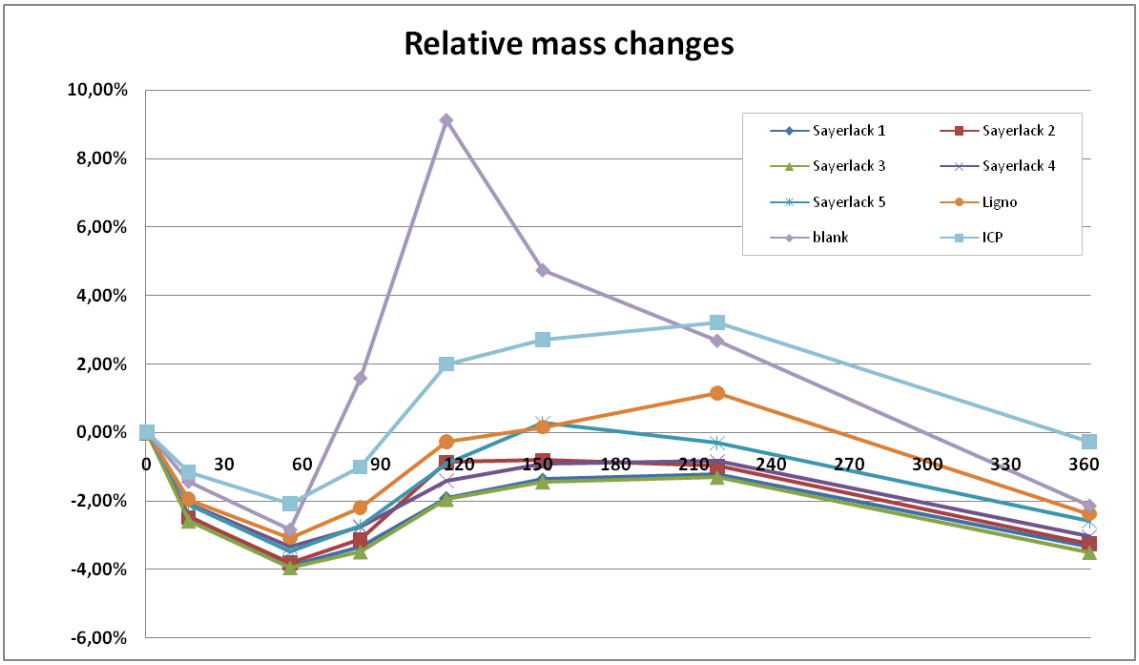
### 3.2.2 Mass changes

*Table 6: Relative (%) mass changes of the specimens throughout the weathering.*

| Weathering duration (days) | | 0-16 | 16-55 | 55-82 | 82-115 | 115-152 | 152-219 | 219-362 |
|---|---|---|---|---|---|---|---|---|
| 1 | Sayerlack 1 | -2,45% | -3,90% | -3,34% | -1,92% | -1,37% | -1,23% | -3,34% |
| 2 | Sayerlack 2 | -2,48% | -3,80% | -3,12% | -0,86% | -0,81% | -0,98% | -3,25% |
| 3 | Sayerlack 3 | -2,58% | -3,94% | -3,48% | -1,94% | -1,43% | -1,30% | -3,49% |
| 4 | Sayerlack 4 | -2,09% | -3,33% | -2,75% | -1,40% | -0,91% | -0,83% | -3,03% |
| 5 | Sayerlack 5 | -2,10% | -3,46% | -2,72% | -0,91% | 0,28% | -0,30% | -2,58% |
| 6 | Adler ligno | -1,95% | -3,07% | -2,19% | -0,28% | 0,15% | 1,14% | -2,39% |
| 7 | blank | -1,43% | -2,83% | 1,59% | 9,12% | 4,74% | 2,68% | -2,14% |
| 8 | ICP | -1,16% | -2,09% | -1,01% | 2,00% | 2,71% | 3,22% | -0,28% |

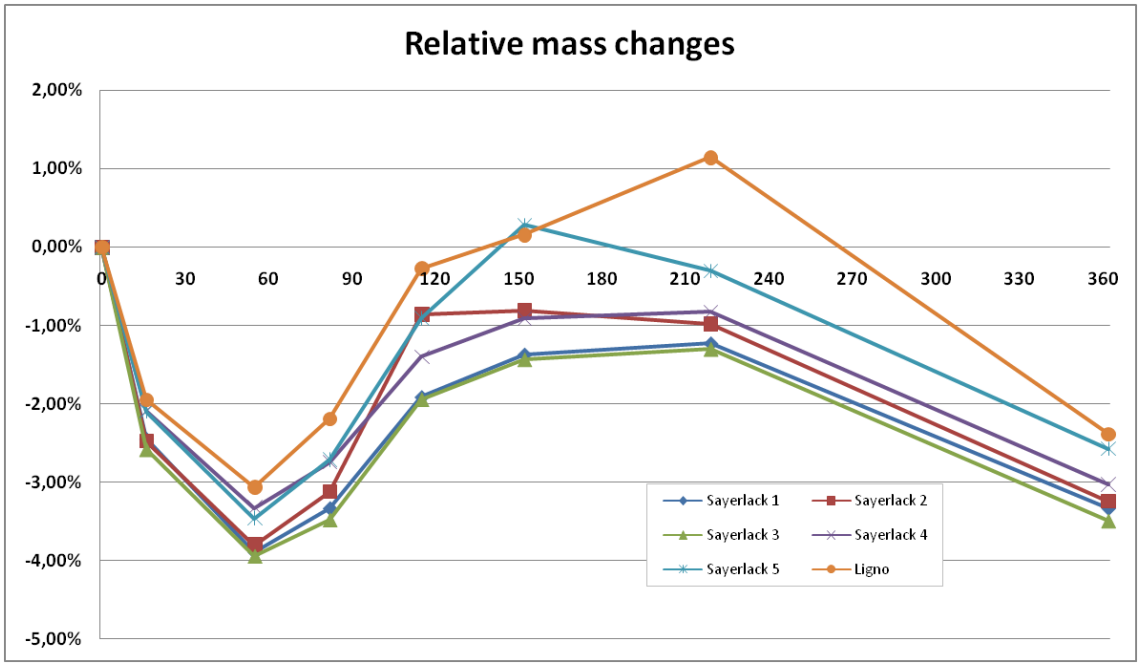



*Graph 5: Absolute mass changes of all specimens throughout weathering*




*Graph 6: Relative mass changes of all specimens throughout weathering*

From Table 6 and *Graph 6* it is obvious that the coating systems tested showed significant improvement (e.g. lower mass changes) of the specimen, probably due to the efficient insulation of them compared to the uncoated ones. With respect to the same property, Ligno and Sayerlack coated specimens followed uniform lines of (lower than blank and ICP samples) changes. This effect can also be clearly observed in Table 8.




*Graph 7: Relative mass changes of the coated specimens throughout weathering*

Graph 7 shows that Sayerlack covered specimens presented slightly higher specimen mass changes compared to Ligno covered ones. Among Sayerlack covered specimens,

the highest mass changes were observed for Sayerlack 3 and Sayerlack 1 covered ones. On the other hand, the lowest mass changes were reported for Sayerlack 5 and Sayerlack 2 coating systems.

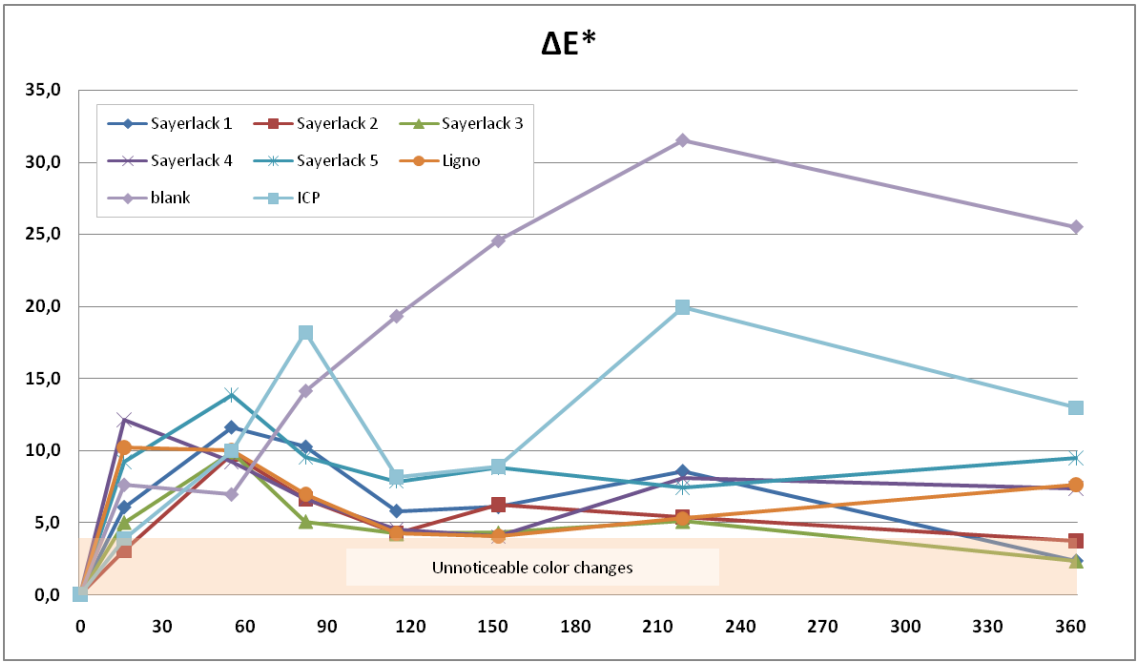
### 3.2.3 Colour changes

*Table 7: Mean values of the determined colour coordinates*

| Weathering days | | | 0 | 16 | 55 | 82 | 115 | 152 | 219 | 362 |
|---|---|---|---|---|---|---|---|---|---|---|
| L* | 1 | Sayerlack 1 | 39,60 | 43,00 | 44,43 | 38,52 | 40,53 | 39,93 | 33,92 | 38,63 |
| | 2 | Sayerlack 2 | 35,77 | 38,47 | 41,85 | 35,22 | 35,77 | 35,70 | 32,73 | 37,03 |
| | 3 | Sayerlack 3 | 34,17 | 38,87 | 41,92 | 34,88 | 36,57 | 35,80 | 32,08 | 35,20 |
| | 4 | Sayerlack 4 | 62,82 | 72,53 | 67,67 | 62,03 | 66,37 | 64,77 | 56,73 | 61,12 |
| | 5 | Sayerlack 5 | 49,00 | 58,02 | 56,08 | 47,78 | 53,43 | 52,27 | 47,40 | 51,85 |
| | 6 | Adler ligno | 65,03 | 73,72 | 72,42 | 61,38 | 68,28 | 67,45 | 61,90 | 68,03 |
| | 7 | blank | 65,50 | 67,58 | 59,67 | 51,88 | 48,50 | 45,45 | 38,23 | 44,84 |
| | 8 | ICP | 95,22 | 93,10 | 86,62 | 77,32 | 88,33 | 86,95 | 75,77 | 89,39 |
| a* | 1 | Sayerlack 1 | 18,68 | 15,43 | 11,88 | 12,80 | 15,67 | 15,70 | 16,87 | 18,18 |
| | 2 | Sayerlack 2 | 11,67 | 10,60 | 8,63 | 9,52 | 11,52 | 11,12 | 13,22 | 11,36 |
| | 3 | Sayerlack 3 | 11,27 | 9,93 | 8,77 | 9,93 | 10,60 | 10,47 | 13,72 | 11,38 |
| | 4 | Sayerlack 4 | 5,37 | 2,72 | 3,23 | 3,90 | 3,92 | 4,70 | 5,90 | 8,90 |
| | 5 | Sayerlack 5 | 13,57 | 13,70 | 11,13 | 7,60 | 16,08 | 14,78 | 14,38 | 19,88 |
| | 6 | Adler ligno | 4,43 | 2,23 | 2,60 | 3,50 | 4,03 | 4,30 | 4,97 | 7,68 |
| | 7 | blank | 3,25 | 5,10 | 6,57 | 5,63 | 4,17 | 1,70 | 3,27 | -2,59 |
| | 8 | ICP | -1,26 | 1,33 | 0,80 | 0,53 | -0,13 | -0,80 | 1,07 | 0,04 |
| b* | 1 | Sayerlack 1 | 31,25 | 27,82 | 23,28 | 23,13 | 26,82 | 26,13 | 25,63 | 29,99 |
| | 2 | Sayerlack 2 | 23,52 | 22,87 | 16,72 | 17,63 | 19,47 | 17,38 | 20,13 | 20,35 |
| | 3 | Sayerlack 3 | 22,35 | 21,47 | 16,98 | 18,43 | 19,22 | 18,93 | 19,07 | 21,76 |
| | 4 | Sayerlack 4 | 25,62 | 18,93 | 18,28 | 19,73 | 23,78 | 22,23 | 20,67 | 31,73 |
| | 5 | Sayerlack 5 | 35,70 | 34,50 | 24,32 | 28,88 | 30,58 | 27,70 | 29,00 | 41,73 |
| | 6 | Adler ligno | 20,93 | 16,22 | 14,63 | 15,55 | 21,83 | 17,90 | 17,88 | 27,06 |
| | 7 | blank | 20,27 | 27,30 | 19,08 | 17,90 | 11,25 | 6,30 | 4,70 | 6,70 |
| | 8 | ICP | 2,20 | 0,27 | 6,70 | 4,70 | 6,17 | 5,23 | 5,90 | 13,70 |

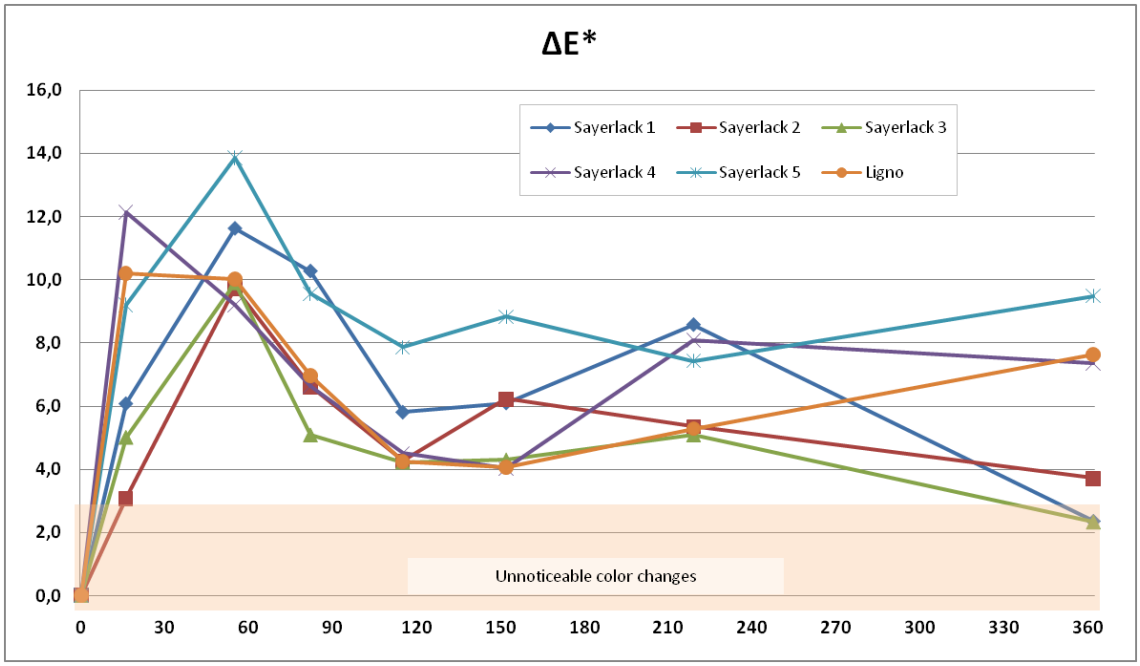
*Table 8: Mean values of the determined individual color coordinate changes and total color changes of the specimens throughout weathering*

| Weathering intervals (days) | | | 0-16 | 16-55 | 55-82 | 82-115 | 115-152 | 152-219 | 219-362 |
|---|---|---|---|---|---|---|---|---|---|
| ΔL* | 1 | Sayerlack 1 | 8,66% | 12,30% | -2,67% | 2,45% | 0,89% | -14,34% | -2,40% |
| | 2 | Sayerlack 2 | 7,55% | 17,03% | -1,57% | 0,01% | -0,17% | -8,44% | 3,59% |
| | 3 | Sayerlack 3 | 13,89% | 22,81% | 2,29% | 7,15% | 4,96% | -5,91% | 3,22% |
| | 4 | Sayerlack 4 | 15,50% | 7,76% | -1,22% | 5,69% | 3,12% | -9,60% | -2,67% |
| | 5 | Sayerlack 5 | 18,42% | 14,42% | -2,44% | 9,06% | 6,68% | -3,31% | 5,83% |
| | 6 | Adler ligno | 13,37% | 11,38% | -5,60% | 5,01% | 3,74% | -4,75% | 4,63% |
| | 7 | blank | 19,18% | 15,39% | -1,37% | 8,09% | 6,28% | -7,81% | 7,05% |
| | 8 | ICP | 16,13% | 9,70% | -3,14% | 7,57% | 4,96% | -13,46% | 5,16% |
| Δa* | 1 | Sayerlack 1 | 19,38% | 11,90% | -2,16% | -10,12% | -12,00% | -22,92% | -11,89% |
| | 2 | Sayerlack 2 | 3,19% | -8,90% | -20,80% | -25,99% | -30,63% | -41,67% | -31,55% |
| | 3 | Sayerlack 3 | -2,23% | -9,04% | -18,81% | -7,24% | -8,69% | -20,43% | -6,13% |
| | 4 | Sayerlack 4 | -17,08% | -36,52% | -31,20% | -16,13% | -15,66% | -9,54% | -2,54% |
| | 5 | Sayerlack 5 | -8,97% | -25,89% | -18,57% | -1,05% | -4,66% | 13,26% | -2,45% |
| | 6 | Adler ligno | -11,72% | -21,58% | -11,48% | -5,85% | -6,78% | 21,79% | 1,10% |
| | 7 | blank | -48,81% | -38,99% | -26,99% | -26,66% | -12,36% | 10,10% | 66,61% |
| | 8 | ICP | 1,15% | -17,79% | -43,50% | 18,85% | 8,96% | 5,98% | 46,89% |
| Δb* | 1 | Sayerlack 1 | -49,15% | -39,57% | -19,76% | -7,13% | -1,91% | 10,94% | 75,29% |
| | 2 | Sayerlack 2 | -20,88% | -41,03% | -21,50% | -3,63% | -6,63% | -0,10% | 11,18% |
| | 3 | Sayerlack 3 | -40,81% | -29,93% | -16,21% | 14,38% | 1,73% | 16,16% | 50,12% |
| | 4 | Sayerlack 4 | -57,08% | -33,66% | -16,53% | -53,22% | -74,19% | -43,42% | -101,83% |
| | 5 | Sayerlack 5 | 57,35% | 113,78% | 85,25% | 35,95% | -43,26% | 9,65% | -191,52% |
| | 6 | Adler ligno | -205,66% | -164,08% | -140,37% | -89,73% | -36,28% | -185,12% | -103,10% |
| | 7 | blank | -10,94% | -25,53% | -26,08% | -14,12% | -16,41% | -17,99% | -4,03% |
| | 8 | ICP | -2,70% | -28,97% | -25,10% | -17,21% | -26,08% | -14,28% | -13,34% |
| ΔE* | 1 | Sayerlack 1 | -3,90% | -24,01% | -17,57% | -14,13% | -15,34% | -14,59% | -2,50% |
| | 2 | Sayerlack 2 | -26,18% | -28,59% | -23,00% | -7,10% | -13,14% | -19,30% | 23,96% |
| | 3 | Sayerlack 3 | -3,33% | -31,87% | -19,12% | -14,17% | -22,34% | -18,68% | 16,87% |
| | 4 | Sayerlack 4 | -22,44% | -30,06% | -25,69% | 4,28% | -14,45% | -14,39% | 29,36% |
| | 5 | Sayerlack 5 | 0,02% | -25,14% | -35,19% | 0,17% | -14,68% | -26,62% | 9,59% |
| | 6 | Adler ligno | -2,47% | -21,47% | -32,80% | -0,72% | -20,70% | -27,87% | 13,27% |
| | 7 | blank | -7,50% | -34,04% | -32,92% | -40,00% | -53,20% | -55,77% | -48,04% |
| | 8 | ICP | 34,92% | -5,80% | -11,67% | -44,49% | -69,02% | -76,70% | -66,74% |



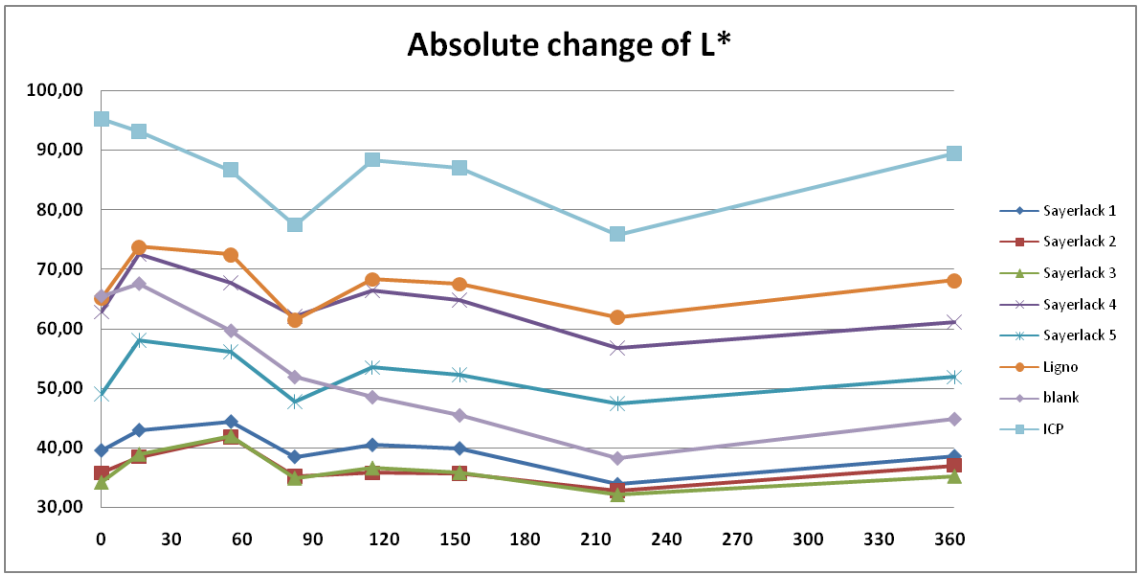

*Graph 8: Total color changes (ΔE* value) of the specimens throughout weathering*

*Graph 8* shows that uncovered specimens (as expected) showed the highest ΔE* values with severe changes occurring throughout the first 7 weathering months and milder changes throughout the rest of the 12 month weathering period. On the contrary, all specimens coated with protective systems showed significant lower total color changes compared to non covered ones.



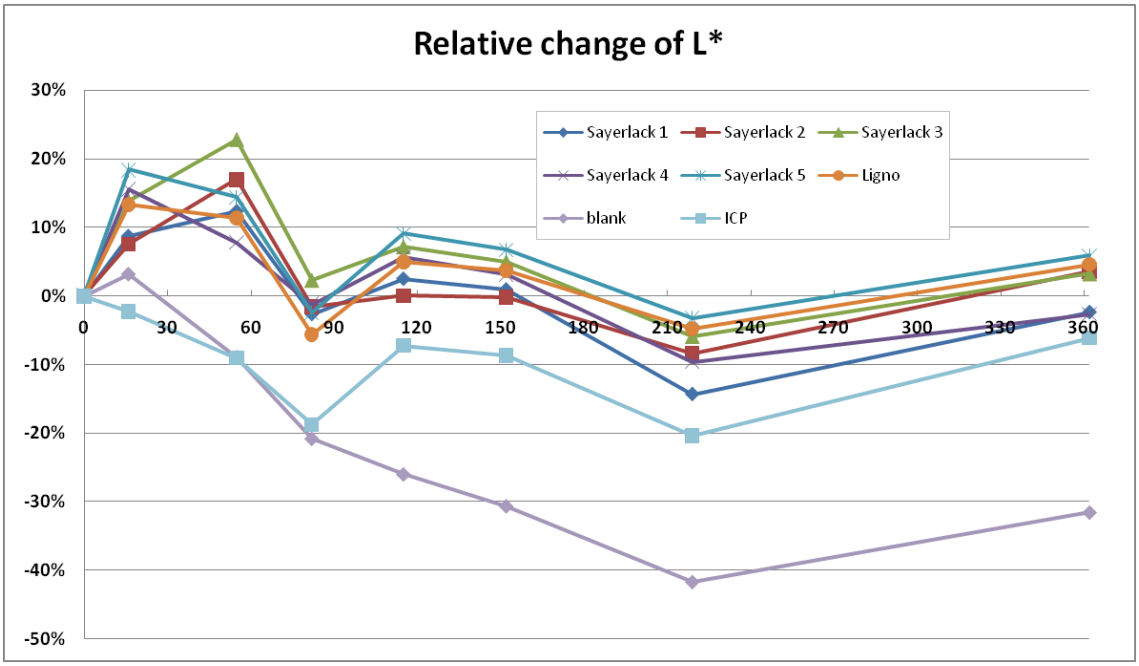

*Graph 9: Total color changes (ΔE* value) of the coated specimens throughout weathering*

*Graph 9* shows that all covered specimens showed severe total color changes throughout the first 2 months of weathering. After the first 2 months a recovery of the changes occurred. After a total of 12 weathering months Sayerlack 1 and Sayerlack 3 specimens did not show noticeable total color changes compared to their initial state. On the contrary, Adler ingo, Sayerlack 4 and Sayerlack 5 showed noticeable color changes compared to their initial state.
Comparing Adler ingo and Sayerlack 3 specimens leads to the conclusion that for the first 2 months of exposure there are similar ΔE* reported while Adler ingo showed much more quicker response. For the next 5 months the behavior of both coatings seems similar and for the last 5 months Adler ingo presents larger total color changes when Sayerlack 3 shows not noticeable (compared to the initial state) total color changes.



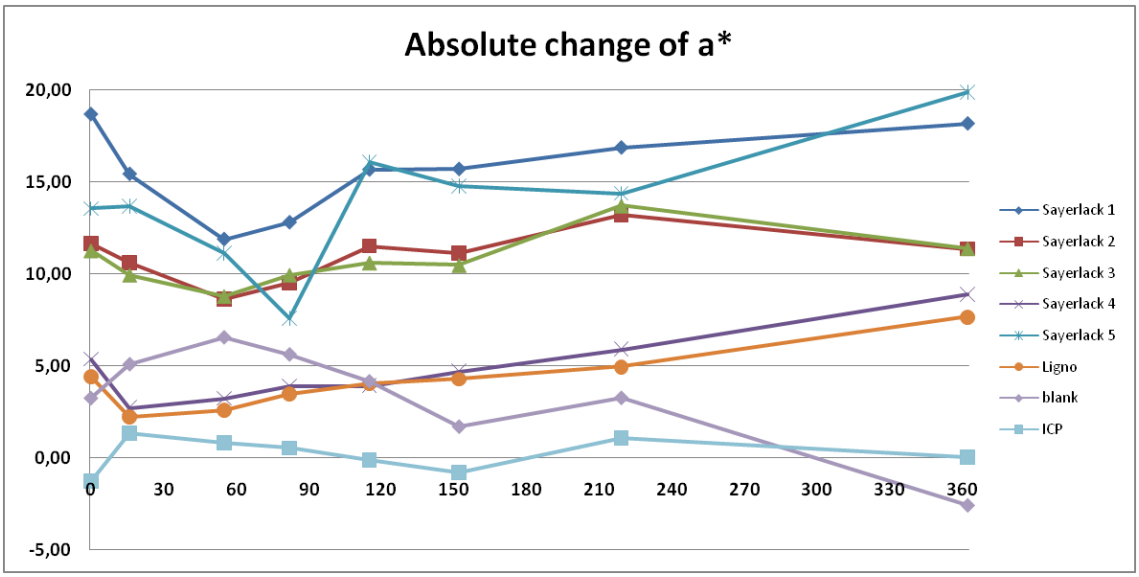

*Graph 10: Absolute lightness (L* value) changes of the specimens throughout weathering*

From *Graph 10* and *Graph 11* it can be observed that all coated specimens show similar tendencies in terms of lightness values. On the contrary, uncoated specimens showed much different behavior mainly characterized by severe lightness changes.
Sayerlack 2 and Sayerlack 3 show similar reaction in terms of Lightness. Sayerlack 1 presents same tendencies but slightly lighter color. Respective changes are shown by Adler ingo and Sayerlack 4 coated specimens.



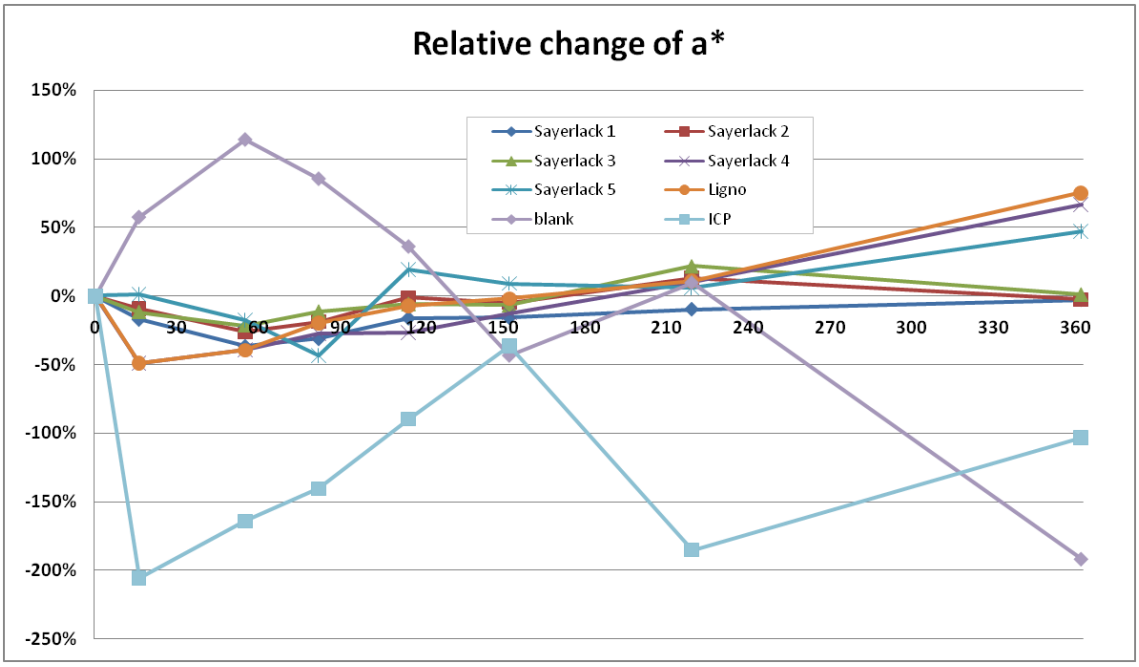

*Graph 11: Relative (%) lightness (L* values) changes of the specimens throughout weathering*

*Graph 10* and *Graph 11* show that the lightness changes occurred during the first half weathering month to uncoated specimens were milder that those of all other coated specimens while the opposites occurred in the rest of the weathering period.
Concerning the covered specimens, they showed lightness raise of 10-20% in the first 2 weathering months but all showed a recovery in the next 10 month period.



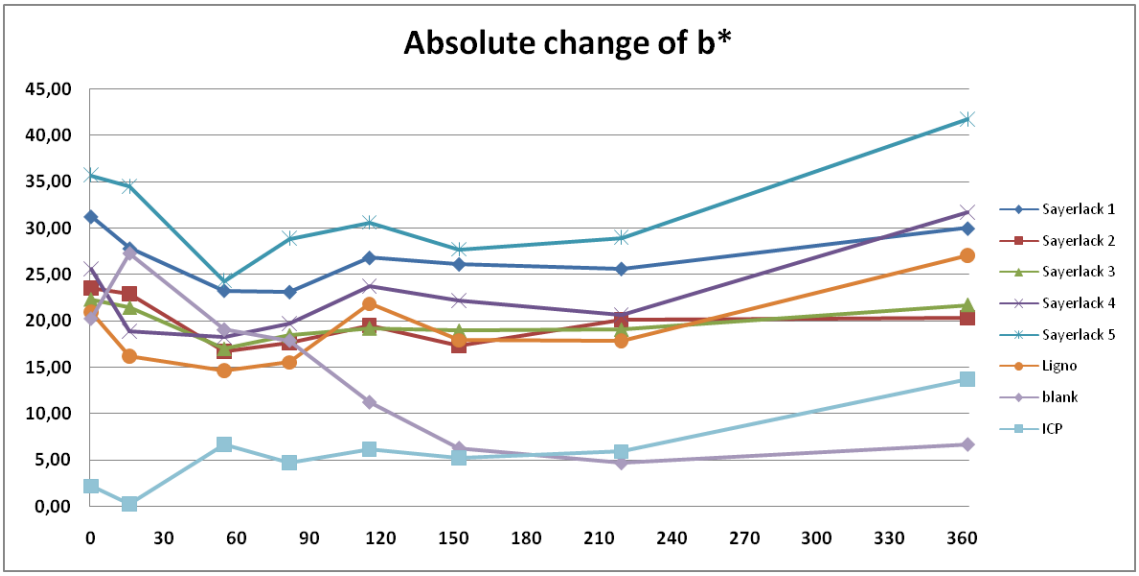

*Graph 12: Absolute redness (a* value) changes of the specimens throughout weathering*

*Graph 12* shows that coated specimens with Sayerlack 1-2-3-5 coating systems showed relatively higher redness changes than the rest of the tested ones. Sayerlack 2 and Sayerlack 3 coatings showed similar behavior. Similar behavior was also reported for Adler ingo and Sayerlack 4 coatings.

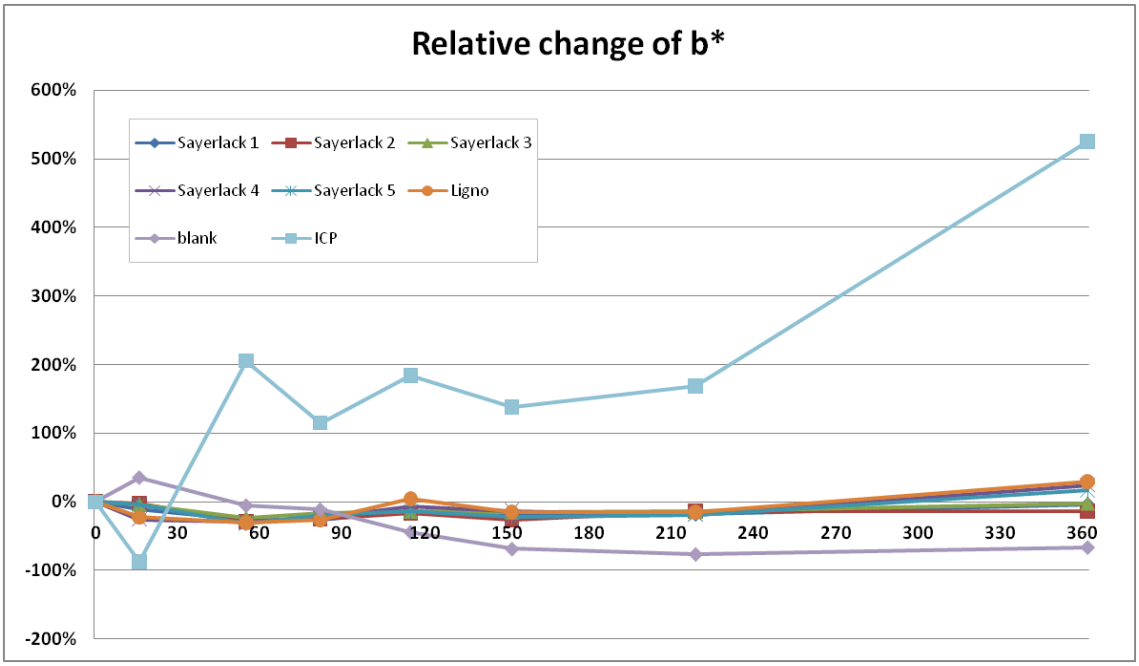



*Graph 13: Relative (%) redness (a* values) changes of the specimens throughout weathering*

*Graph 13* shows that Sayerlack 1-2-3 coated specimens after 12 months of weathering showed almost none final redness changes. On the contrary, after the 12 month weathering period, Adler ingo, Sayerlack 4 and Sayerlack 5 specimens showed an increase of redness by about 50%.

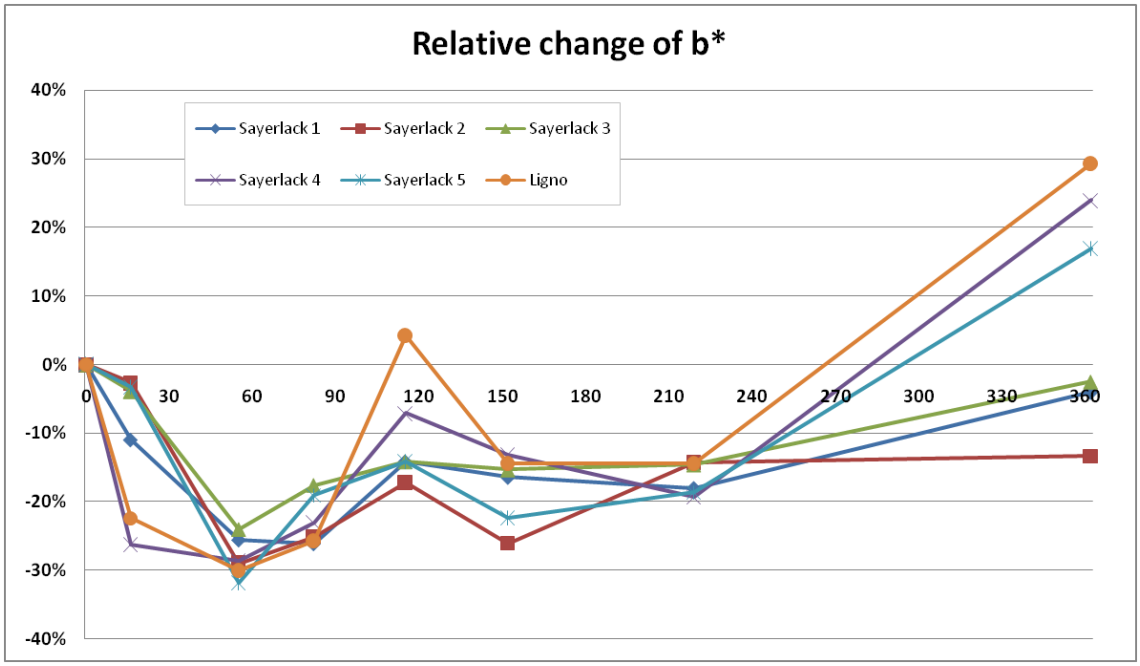



*Graph 14: Absolute yellowness (b* value) changes of the specimens throughout weathering*




*Graph 15: Relative (%) yellowness (b* values) changes of the specimens throughout weathering*

*Graph 15* shows that the most severe relative b* value changes occurred to ICP and uncoated specimens. The other coated specimens showed milder yellowness changes.




*Graph 16: Relative (%) yellowness (b* values) changes of the covered specimens throughout weathering*

Concerning the coated specimens, after the first 2 month weathering period there was a yellowness reduction of 20-30% but still positive values (yellow color). The following 2 months (third and fourth weathering months) a recovery of the above changes occurred. Best recovery behavior after a total of 4 weathering months was presented by Sayerlack 4 and Adler ingo specimens. Finally, after 12 weathering months, the best yellowness recovery behavior was reported for Sayerlack 3 and Sayerlack 5 specimens, thus the poorest recovery of same property was reported for Adler ingo specimens.

### 3.2.4 Macroscopically detected defects

Generally all coated specimens did not show any significant macroscopically detected defects except of the cases shown in the Figures below.

*Figure 3: Coating layer delamination occurred to specimen coated with Sayerlack 3 coating system*

In *Figure 4* three delamination areas (two limited and one extended) of coating layer occurred for a Sayerlack 3 coating system is shown.

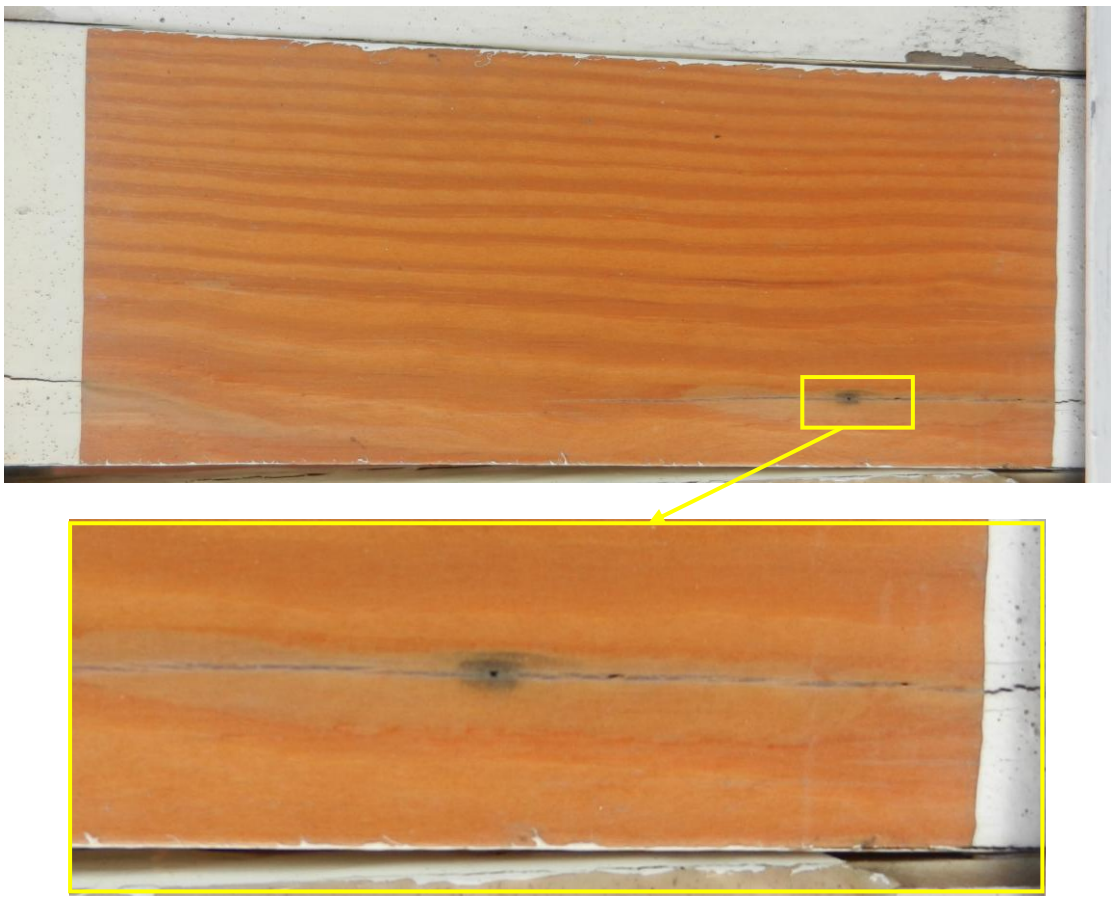


*Figure 4: Surface check occurred to specimen coated with Sayerlack 5 coating system*

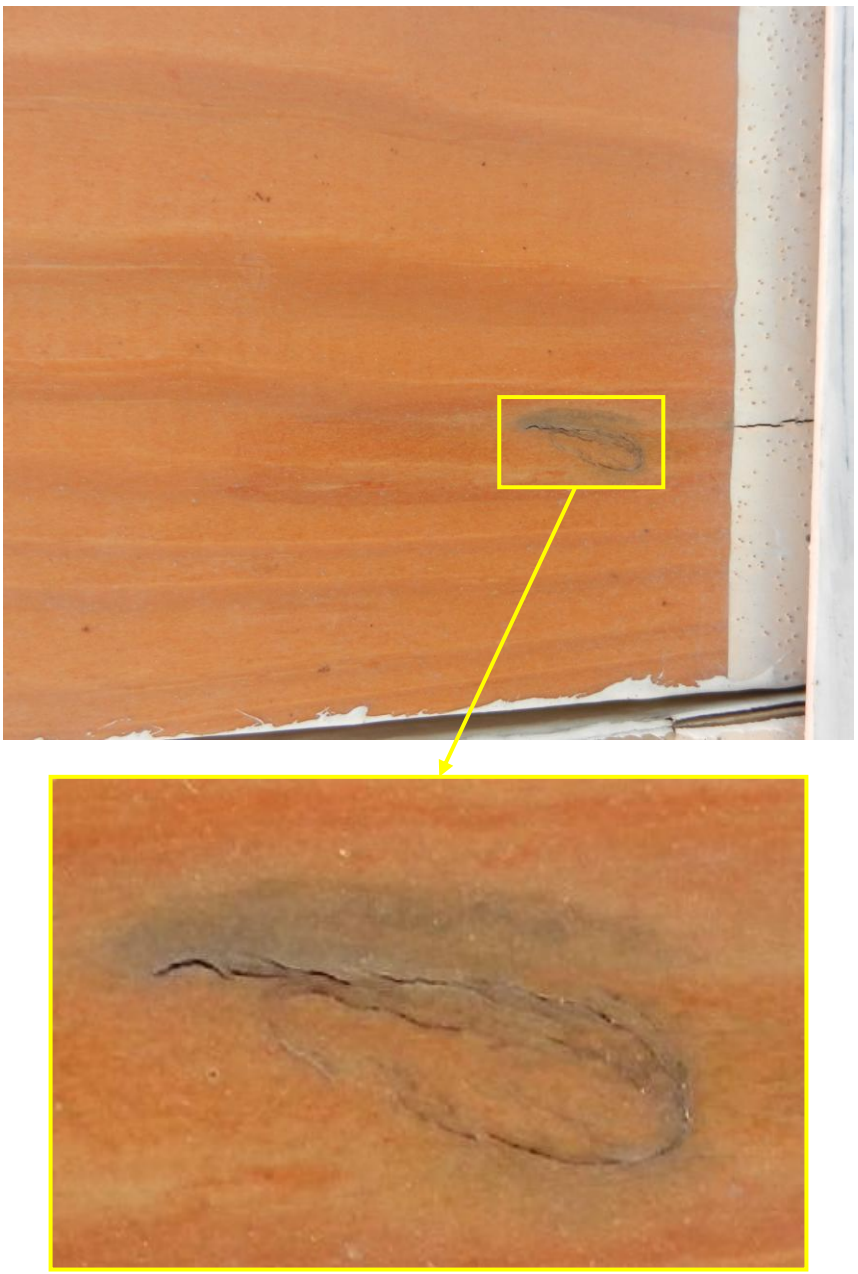


*Figure 5: Surface check occurred to specimen coated with Sayerlack 5 coating system*

*Figure 4* and *Figure 5* show defects observed for two Sayerlack 5 covered specimens. Both of them seem to have occurred due to impact of some article on the specimen surface. Considering the shape of the impact area the above defects could probably be attributed to hail fall.

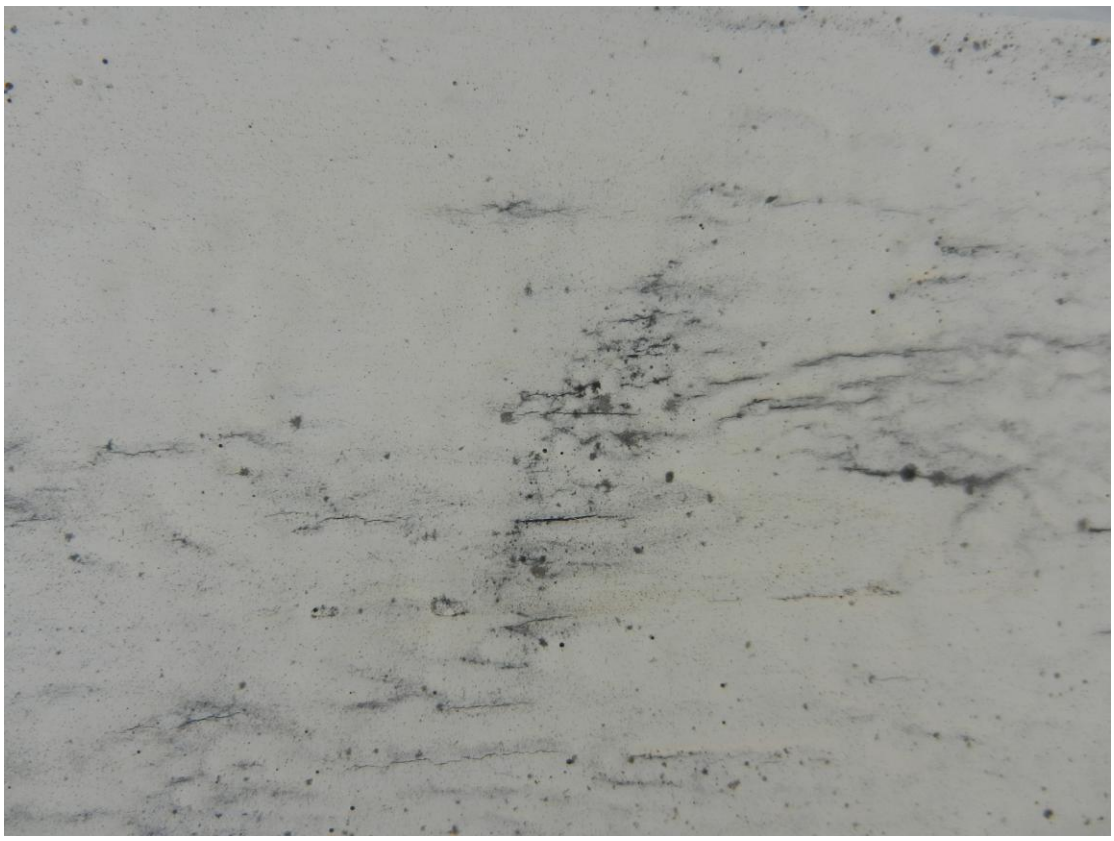


*Figure 6: Black stain occurring on ICP covered specimens*

All of the ICP covered specimens showed black stains on all surfaces (exposed and unexposed). Representative examples are shown in *Figure 6*.

---------- End ----------

Signing this report

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