门窗用聚氯乙烯型材耐候老化测试研究

Weathering Testing of PVC for Windows and Doors

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试验目的
Purpose of the Test

- 分析PVC样品在户外曝晒、实验室加速老化试验中的颜色变化，并计算它们之间的相关性
- To analyze color change of PVC specimens in outdoor exposure and in lab testing respectively
- To calculate correlation between the two testing methods
- 确定能否采用紫外加速老化测试方法作为PVC型材的实验室加速老化试验方法
- To determine whether the UV accelerated weathering test can be used for PVC lab accelerated weathering testing

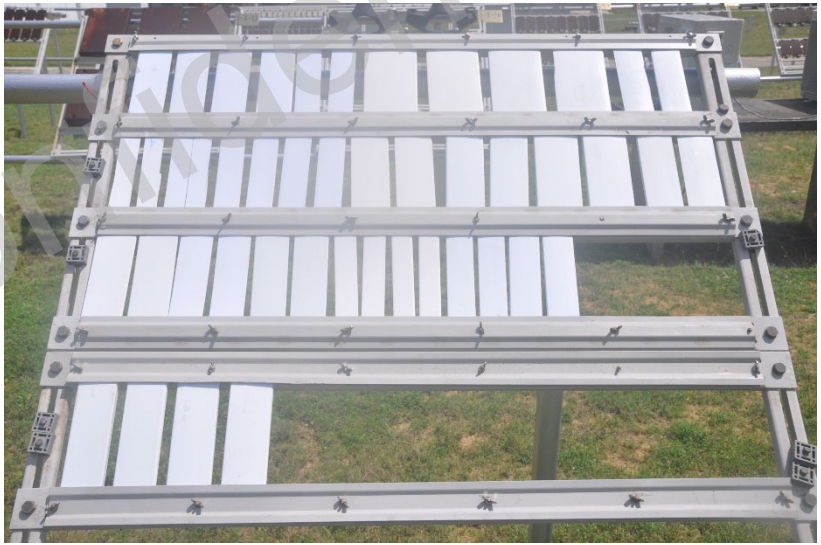
参与单位
Cooperation

- 中国建筑金属结构协会塑料门窗委员会
- China Architecture Metal Structure Association – Plastic Window and Door Committee
- 美国Q-Lab公司中国代表处
- Q-Lab Corporation China Office

户外曝晒
Outdoor Exposure

- 曝晒地点：exposure locations
  - 乌鲁木齐（干旱气候）Urumchi (arid climate)
  - 福州（亚热带气候）Fu Zhou (subtropical climate)
  - 格尔木（高原气候）Ge Er Mu (plateau climate)
- 曝晒角度：45°朝南
- 45°south exposure angle
- 背板技术：无背板
- Backing techniques: Open-backed exposure

户外曝晒
Outdoor Exposure



实验室加速试验
Lab Accelerated Weathering Test

- Q-SUN 氙灯试验箱
- Q-SUN xenon test chamber

- QUV 紫外老化试验机
- QUV accelerated weathering tester

实验室加速试验
Lab Accelerated Weathering Test

Q-SUN氙灯试验箱

QUV紫外老化试验机

户外 vs. 实验室
Outdoor Exposure vs. Lab Testing

+

试验样品
Test Specimens

- 试验样品 test specimen
  - 共27种 27 specimens in all
- 其中3号，10号，11号，12号，20号，22号，23号，24号，27号这9种样品为彩色
  - Specimen numbers 3, 10, 11, 12, 20, 22, 23, 24, and 27 are colored
  - 其余为白色 The remaining specimens are white

氙灯加速老化试验条件
Xenon accelerated weathering test conditions

测试设备 tester	氙灯加速老化试验箱 Xenon test chamber
滤光器 filter	日光滤光器 daylight filter
辐照度 irradiance	0.51 W/m^2 @340nm
黑标温度 BST	65 °C
箱体空气温度 chamber air temp	38 °C
相对湿度 HR	50 %
喷淋 spray	102 mins sunlight；18 mins sunlight +spray

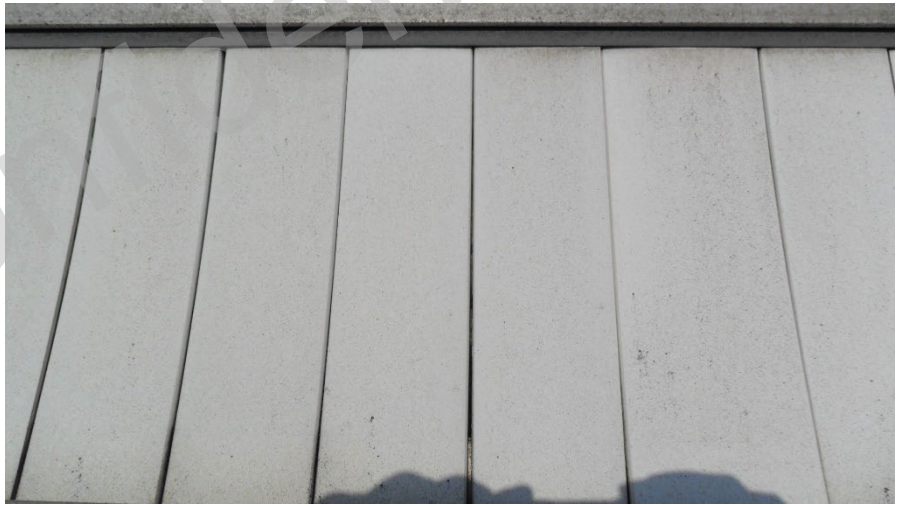
注：以上试验条件参照GB/T 8814中的规定
Note : according to GB/T 8814

紫外加速老化试验条件
UV accelerated weathering test conditions

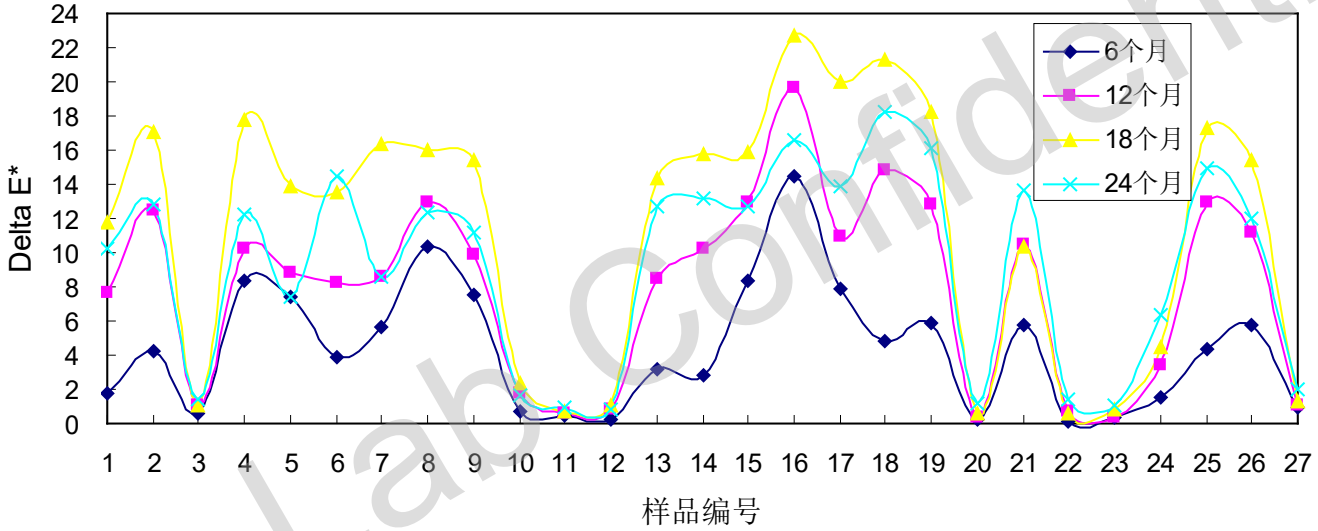
试验设备 tester	QUV紫外加速老化试验机 UV accelerated weathering tester
试验灯管 lamp	UVA-340灯管 UVA-340 lamp
辐照度 irradiance	1.00 W/m^2@340nm
黑板温度 BPT	60 °C（光照循环）(UV step) 50 °C（冷凝循环）(condensation step)
测试循环 test circle	8h（光照循环）(UV step) 4h（冷凝循环）(condensation step)

注：以上试验条件参照VSI (Vinyl Siding Institute)和ASTM G154标准
Note : according to VSI (Vinyl Siding Institute) and ASTM G154

户外曝晒试验结果
Outdoor Exposure Test Results



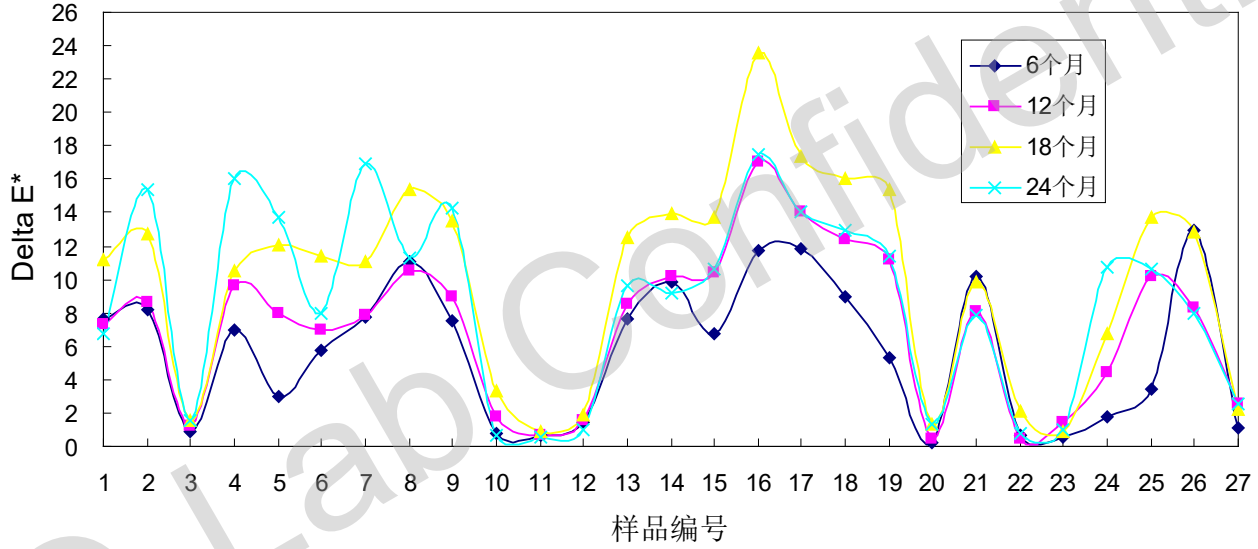
户外曝晒试验结果
Outdoor Exposure Test Results



样品在乌鲁木齐曝晒后的颜色变化
Color change of specimens after exposure in Urumchi

户外曝晒试验结果

Outdoor Exposure Test Results

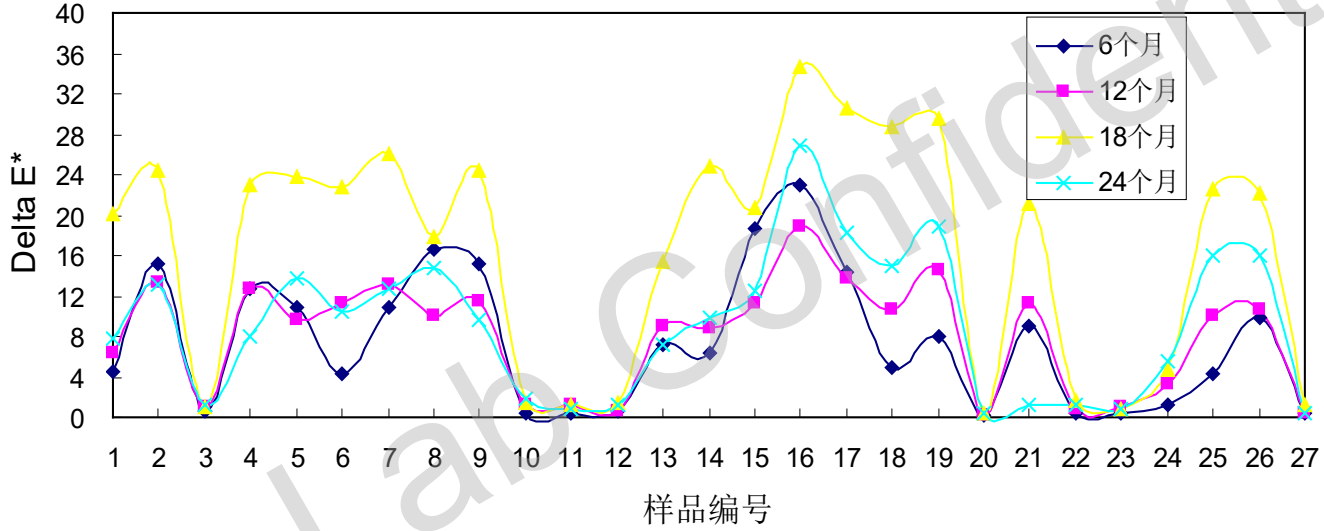


样品在福州曝晒后的颜色变化

Color change of specimens after exposure in Fu Zhou

户外曝晒试验结果

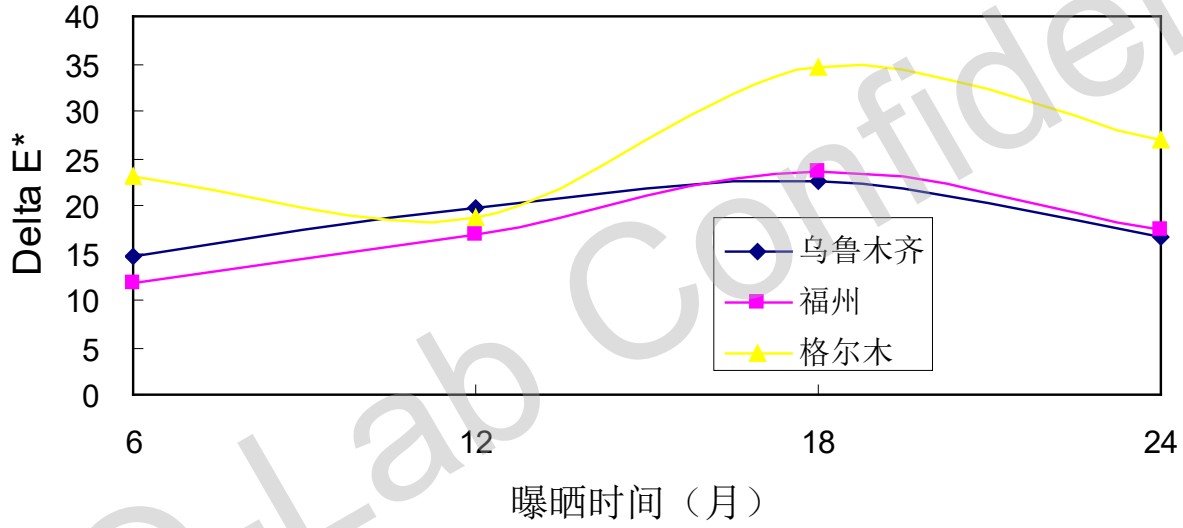
Outdoor Exposure Test Results



样品在格尔木曝晒后的颜色变化

The color changing of the specimen after exposure in Ge Er Mu

户外曝晒试验结果
Outdoor Exposure Test Results



16号样品在户外不同曝晒时间发生的颜色变化

The color changing of the specimen #16 under different exposure time in outdoor

户外曝晒试验结果
Outdoor Exposure Test Results

- 户外曝晒24个月样品的颜色变化没有曝晒18个月的颜色变化厉害
  - Specimens undergoing 18 months outdoor exposure have more pronounced change than specimens undergoing 24 months
- 所有样品都未出现粉化状况
  - No chalking happened
- 这种情况可能与户外污染物有关
  - This situation can be related to outdoor pollutant
- 彩色样品相比白色样品颜色变化很小
  - Colored specimens did not have more pronounced change than white specimens

相关性
Correlation

- 利用排序方法来确认曝晒结果
  - Apply the method of rank order to confirm the exposure result
- 把样品从好到差或从差到好进行排序
  - Rank specimens from best to worst
- 使用Spearman相关系数计算两种方法之间的相关性
  - Calculate Spearman Correlation Coefficient between the two methods
  - $r_s=1-6\sum d_i^2/[n(n^2-1)]$
- 相关系数最大为1，最小为-1
  - Spearman Correlation Coefficient is from -1 to 1

户外曝晒之间的相关性

Correlation of Outdoor Exposure

相关系数r_s	乌-6月	福-6月	乌-12月	福-12月	乌-18月	福-18月	乌-24月	福-24月
乌-6月	1	—	—	—	—	—	—	—
福-6月	0.74	1	—	—	—	—	—	—
乌-12月	0.85	0.78	1	—	—	—	—	—
福-12月	0.86	0.78	0.94	1	—	—	—	—
乌-18月	0.83	0.75	0.91	0.94	1	—	—	—
福-18月	0.79	0.78	0.91	0.95	0.89	1	—	—
乌-24月	0.70	0.72	0.87	0.87	0.84	0.87	1	—
福-24月	0.82	0.65	0.73	0.77	0.86	0.72	0.63	1

乌鲁木齐与福州曝晒结果之间的相关性

Correlation of outdoor exposure between Urumchi and Fu Zhou

户外曝晒之间的相关性

Correlation of Outdoor Exposure

相关系数r_s	乌-6月	格-6月	乌-12月	格-12月	乌-18月	格-18月	乌-24月	格-24月
乌-6月	1	—	—	—	—	—	—	—
格-6月	0.93	1	—	—	—	—	—	—
乌-12月	0.85	0.8	1	—	—	—	—	—
格-12月	0.85	0.84	0.79	1	—	—	—	—
乌-18月	0.83	0.79	0.91	0.86	1	—	—	—
格-18月	0.73	0.73	0.78	0.88	0.88	1	—	—
乌-24月	0.70	0.61	0.87	0.77	0.84	0.79	1	—
格-24月	0.76	0.72	0.86	0.78	0.89	0.85	0.76	1

乌鲁木齐与格尔木曝晒结果之间的相关性

Correlation of outdoor exposure between Urumchi and Ge Er Mu

户外曝晒之间的相关性

Correlation of Outdoor Exposure

相关系数r_s	福-6月	格-6月	福-12月	格-12月	福-18月	格-18月	福-24月	格-24月
福-6月	1	—	—	—	—	—	—	—
格-6月	0.79	1	—	—	—	—	—	—
福-12月	0.78	0.81	1	—	—	—	—	—
格-12月	0.72	0.84	0.80	1	—	—	—	—
福-18月	0.78	0.75	0.95	0.74	1	—	—	—
格-18月	0.73	0.73	0.82	0.88	0.84	1	—	—
福-24月	0.65	0.84	0.77	0.83	0.72	0.83	1	—
格-24月	0.7	0.72	0.85	0.78	0.90	0.85	0.74	1

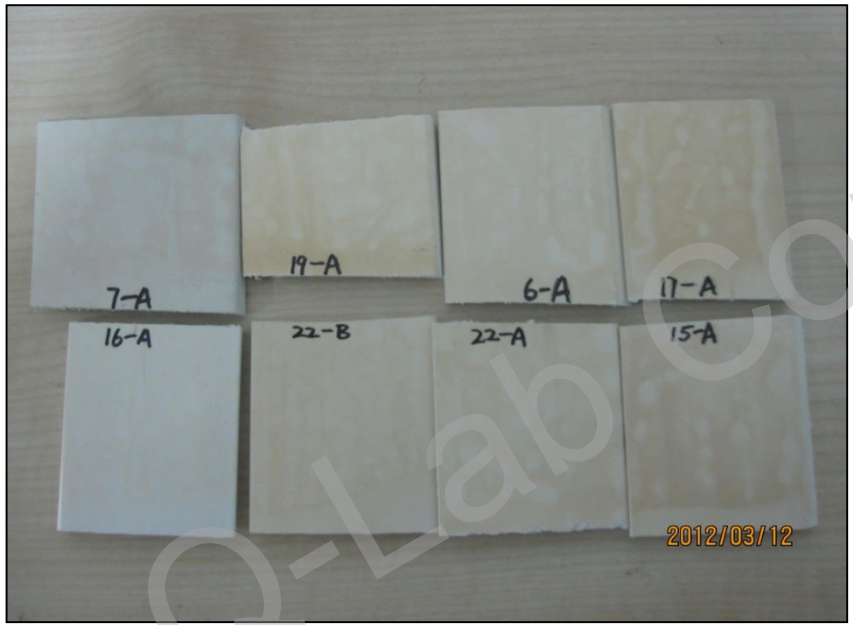
福州与格尔木曝晒结果之间的相关性

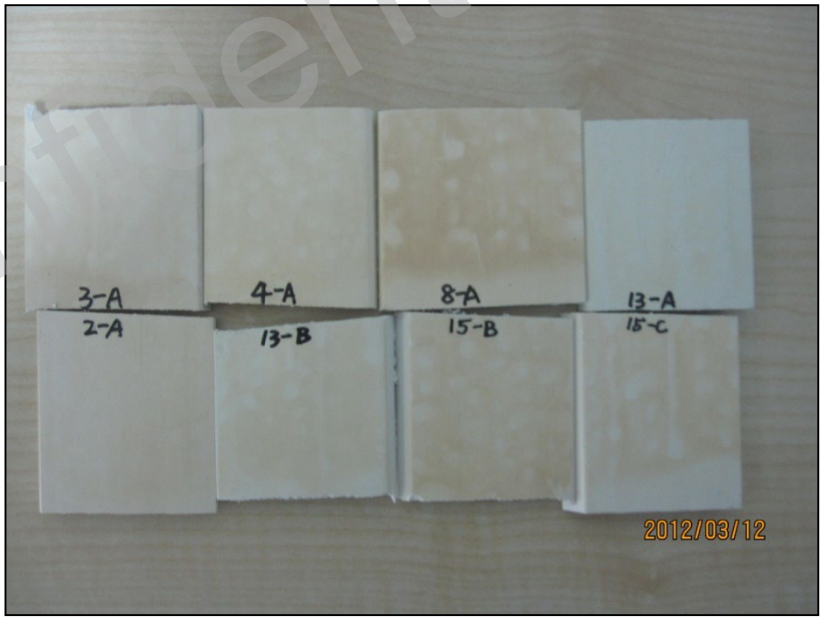
Correlation of outdoor exposure between Fu Zhou and Ge Er Mu

户外曝晒之间的相关性
Correlation of Outdoor Exposure

- 户外曝晒结果之间的相关性较好
  - The correlation of outdoor exposure is quite good
- 3个不同曝晒地点、不同曝晒时间之间的相关系数绝大多数都大于0.70
  - Most correlation coefficients of the 3 different exposure sites and the different exposure time are > 0.70
- 在福州曝晒12个月和曝晒18个月之间的相关系数甚至高达0.95
  - 0.95 is a high correlation coefficient between 12 months and 18 months in the same site (Fu Zhou)

氙灯加速老化试验结果
Xenon Accelerated Weathering Test Results





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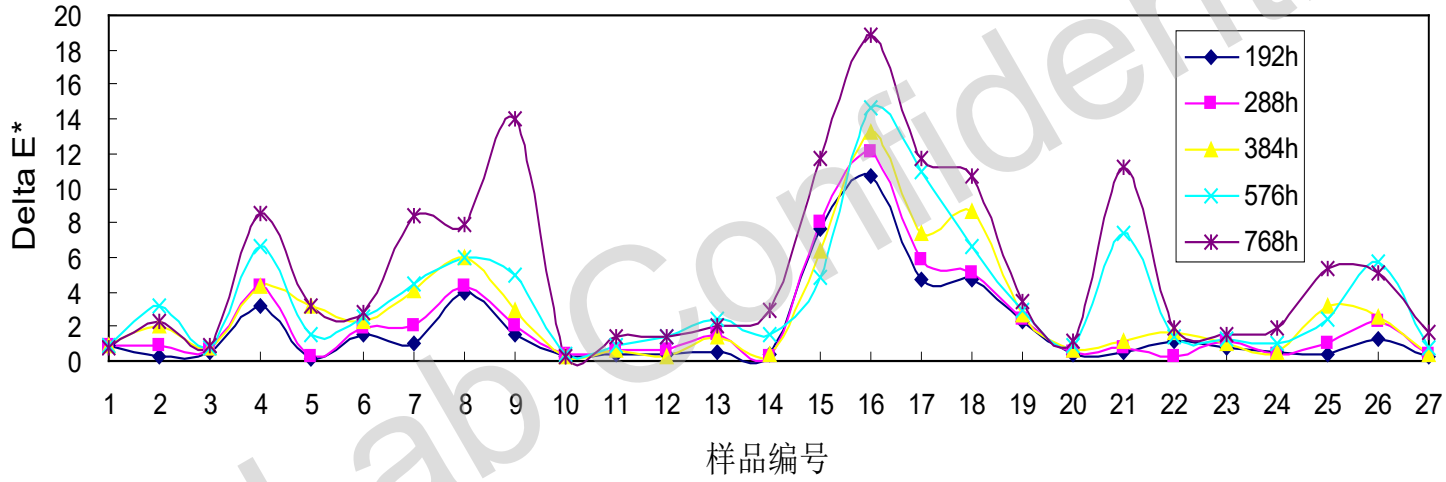


氙灯试验箱中样品的颜色变化
Color change of specimens in Xenon test chamber

氙灯加速老化试验结果
Xenon Accelerated Weathering Test Result

- 氙灯试验箱中样品的颜色变化一般是随着试验时间的增加而变大
  - In general, as time goes on, the color changing of the specimen in Xenon test chamber has more pronounced change

- 同户外曝晒一样，也是彩色样品颜色变化较小
  - Color change of colored specimens are not more pronounced than the change from outdoor exposure; it is very small in both tests

氙灯试验与户外曝晒之间的相关性

Correlation Between Xenon Testing and Outdoor Exposure

相关系数r_s	氙灯-192h	氙灯-288h	氙灯-384h	氙灯-576h	氙灯-768h
乌-6月	0.61	0.73	0.83	0.84	0.87
福-6月	0.48	0.61	0.58	0.81	0.70
格-6月	0.53	0.69	0.75	0.82	0.82
乌-12月	0.54	0.68	0.76	0.80	0.80
福-12月	0.58	0.73	0.75	0.80	0.81
格-12月	0.60	0.73	0.76	0.83	0.81
乌-18月	0.56	0.74	0.79	0.78	0.77
福-18月	0.55	0.65	0.72	0.73	0.74
格-18月	0.48	0.55	0.70	0.75	0.76
乌-24月	0.53	0.62	0.65	0.73	0.71
福-24月	0.45	0.59	0.76	0.74	0.77
格-24月	0.52	0.63	0.76	0.69	0.66

氙灯试验与户外曝晒之间的相关性

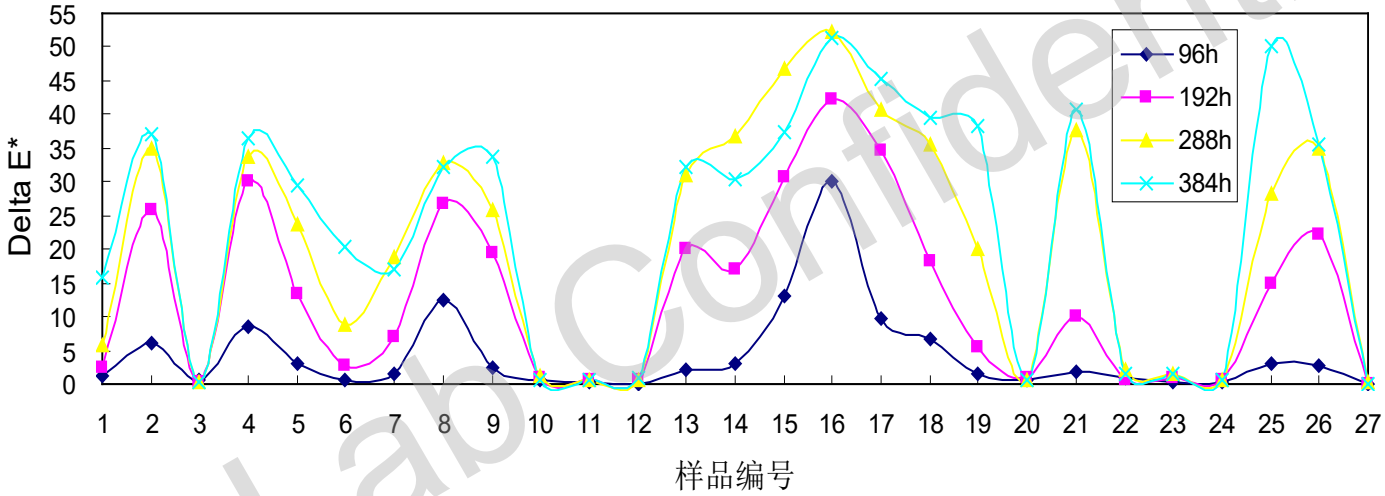
Correlation Between Xenon Testing and Outdoor Exposure

- 氙灯试验与乌鲁木齐，福州和格尔木之间的相关性差不多
  - Correlation of the Xenon testing is nearly the same with exposures in Urumchi, Fu Zhou, and Ge Er Mu
- 除了曝晒192小时，氙灯试验与户外曝晒之间的相关性较好
  - Correlation is quite good between Xenon testing and the outdoor exposure, except the 192 hours exposure
- 氙灯试验768小时≈乌鲁木齐，福州和格尔木6个月
  - Xenon testing for 768 hours ≈ exposure in Urumchi, Fu Zhou or Ge Er Mu for 6 months
- 氙灯试验768小时与户外曝晒相关系数的平均值为0.80
  - Average correlation coefficient is 0.80 between Xenon testing for 768 hours and outdoor exposure

紫外加速老化试验结果

UV Accelerated Weathering Test Results

紫外加速老化试验结果
UV Accelerated Weathering Test Results



紫外试验机中样品的颜色变化
Color change of specimens in UV tester

紫外加速老化试验结果
UV Accelerated Weathering Test Results

- 紫外试验机中样品的颜色变化一般是随着试验时间的增加而变大
  - In general, as time goes on, the color changing of the specimen in UV tester has more pronounced change
- 同户外曝晒和氙灯试验一样，也是彩色样品颜色变化较小
  - Color change of colored specimens are not more pronounced than the change from outdoor exposure; it is very small in both tests

紫外试验与户外曝晒之间的相关性

Correlation Between UV Testing and Outdoor Exposure

相关系数r_s	QUV-96h	QUV-192h	QUV-288h	QUV-384h
乌-6月	0.83	0.84	0.77	0.78
福-6月	0.72	0.79	0.83	0.73
格-6月	0.82	0.87	0.79	0.74
乌-12月	0.87	0.82	0.84	0.89
福-12月	0.86	0.85	0.85	0.88
格-12月	0.72	0.77	0.75	0.83
乌-18月	0.82	0.81	0.77	0.84
福-18月	0.83	0.80	0.81	0.82
格-18月	0.71	0.70	0.74	0.79
乌-24月	0.71	0.69	0.79	0.86
福-24月	0.71	0.72	0.63	0.68
格-24月	0.75	0.73	0.68	0.78

紫外试验与户外曝晒之间的相关性
Correlation Between UV Testing and Outdoor Exposure

- QUV紫外试验机与乌鲁木齐，福州和格尔木之间的相关性差不多
  - Correlation from UV testing is nearly the same with exposures in Urumchi, Fu Zhou and Ge Er Mu
- 紫外试验192小时≈乌鲁木齐，福州和格尔木18个月
  - UV testing for 192 hours ≈ exposure in Urumchi, Fu Zhou or Ge Er Mu for 18 months
- 紫外试验192小时与户外曝晒相关系数的平均值为0.77
  - Average correlation coefficient is 0.77 between the UV testing for 192 hours and outdoor exposure
- 紫外试验加速倍率≈12倍氙灯试验加速倍率
  - The acceleration factor for UV ≈ 12* accelerating rate for Xenon

结论
Conclusions

- 户外曝晒会受到很多环境因素的影响，如样品表面的灰尘等污染物对样品颜色变化数据会产生比较大的影响
  - Outdoor exposure is affected by environment. For example, dust on specimen surfaces can have a pronounced effect on color change data
- 户外曝晒结果之间的相关性较好
  - Correlation of outdoor exposure is quite good
- 氙灯试验与户外曝晒之间的相关系数的平均值是0.80
  - Average correlation coefficient is 0.80 between Xenon testing and outdoor exposure
- 紫外试验与户外曝晒之间的相关系数的平均值是0.77
  - Average correlation coefficient is 0.77 between UV testing and outdoor exposure

结论
Conclusions

- 氙灯试验768小时≈乌鲁木齐，福州和格尔木6个月
  - Xenon testing for 768 hours ≈ exposure in Urumchi, Fu Zhou, or Ge Er Mu for 6 months
- 紫外试验192小时≈乌鲁木齐，福州和格尔木18个月
  - UV testing for 192 hours ≈ exposure in Urumchi, Fu Zhou, or Ge Er Mu for 18 months
- 紫外试验加速倍率≈12倍氙灯试验加速倍率
  - The acceleration factor for UV ≈ 12* accelerating rate for Xenon
- 紫外试验不但与户外曝晒之间的相关性好，而且可以更快地得到测试结果
  - UV testing has good correlation with outdoor exposure as well as fast results

Thank you for your attention!

Questions?

Send your inquiry to:
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