The Study on Durability Testing of Heat-insulation Coating

CHEN Chien-fu[a], HUANG Yuan-chang[b], HO Ming-chin[c], LIN Yu-hsin[d], LEE Shin-ku[e]

[a] *National Cheng-Kung University, Taiwan, jeffjeffchen78@gmail.com*
[b] *Material and Chemical Research Laboratories, Industrial Technology Research Institute, Taiwan, huangyc@itri.org.tw*
[c] *Architecture and Building Research Institute, Ministry of the Interior, Taiwan, 2010hmc@gmail.com*
[d] *Architecture and Building Research Institute, Ministry of the Interior, Taiwan, hsin1020@abri.gov.tw*
[e] *National Cheng-Kung University, Taiwan, sklee1015@gmail.com*

ABSTRACT

Building energy consumption accounts for the proportion of total national energy consumption is quite large, such as the United States accounts for about 40% of total energy consumption, Taiwan for about 30%, and China for 25%. The current strategy to reduce the energy consumption of the building is not only to improve energy efficiency of equipment in buildings (such as the use of high-efficiency air conditioning, lighting, etc.), but also to develop heat insulation materials for building envelopes. This study aims to investigate the relation between optical performance and durability of the heat insulation paint. 23 kinds of heat insulation paint on the market were selected to conduct the natural exposure testing and artificial accelerated aging testing, respectively, and the solar reflectance and emissivity of all samples were measured and compared.

The experimental results indicate that the test samples could produce blue-green algae and dust on the surface due to water vapour in the atmosphere, so the solar reflectance of the samples would have more significant decline. After 2000 hours artificial accelerated aging testing, the emissivity and solar reflectance was reduced by 2% and 10%, respectively.

Keywords: *heat-insulation coating, durability, accelerated weathering test, solar reflectance, emissivity*

1. INTRODUCTION

All countries in the world are investing a lot of manpower and resources to solve climate change and global warming problems. Energy consumption of building sector accounts for a country's total energy consumption is quite large. For example, building energy consumption accounts for about 40% of the total energy consumption in the United States, Taiwan is about 30%, China about 25%. Therefore, reducing the building energy consumption and urban heat island effect have become one of the most important issues in the world. The current strategy to reduce the energy consumption of the building is not only to improve energy efficiency of equipment in buildings (such as the use of high-efficiency air conditioning, lighting, etc.), but also to develop high performance heat insulation materials for building envelope. It is well known that installation of heat-insulated materials, insulation coatings and energy-saving windows in building envelope has a significant effect on reducing energy consumption. Cool Roof with high thermal insulation performance to reduce the roof temperature, has been proven by the US Environmental Protection Agency. Using cool roof material has been selected as one of the effective strategies to reduce building energy consumption and urban heat island effect.

In the past three decades, many accelerated weathering techniques have been developed and utilized to meet the requirement of rapid development of new cool roof materials. These accelerated test methods attempt to accelerate natural environments with higher stress, e.g. greater intensity of UV radiation and elevated temperature without changing the failure mechanism. With these methods, the performance of cool roof material can be estimated in a short test period. Among those accelerated weathering test methods, a QUV chamber and a xenon arc chamber have been commonly used in industry and academia to test the weathering durability of the coatings. In these two chambers, UVA or filtered xenon-arc radiation and water condensation are provided alternately.

In Taiwan, insulation coatings are cheaper and easier to use than other construction materials. They have been widely used in residential building facades and roofs, industrial manufactory, schools and even farmhouses. However, the claims of thermal insulation properties and durability of the coating are not compulsory requirement, a product-related information between insulation performance and durability of commercially available insulation coating so far is not unified in Taiwan. Therefore, it is necessary to develop the durability testing methods for insulation coating in order to encourage consumers and architects to use more insulation paint. The natural phenomena can cause degradation in polymer systems. The elements of most concern to paints are ultraviolet radiation, moisture, humidity, high temperatures and temperature fluctuations. Thus, it is important for scientists and paint producers to understand durability and expected lifespan of paint products. This study aims to investigate the relation between optical performance and durability of the heat insulation paint.

2. TEST METHOD

The 23 kinds of commercially available paints were collected in this study. The colors of these samples are white, grey, green, blue and red. These paints were coated on the cement brick and steel substrates by using an RDS coating bar (no. 22, coating thickness: 50.29 μm), respectively. The sizes of steel substrate are 10 x 10 x 0.05 and 7 x 14 x 0.05 (length, width, height, cm), and size of cement brick substrate is 10 x 10 x 1 (length, width, height, cm).

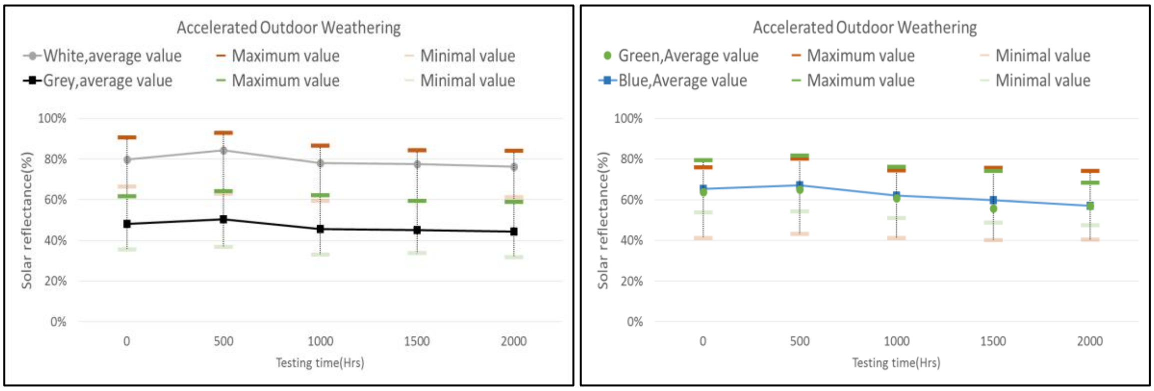
Samples were subjected to natural weathering, xenon-arc lamp artificial weathering and UV lamp accelerated natural weathering based on CNS 15200 and CNS 1183, respectively. The testing conditions of these three tests are listed in Table 1. The total duration of the test was 2000 hr. Before and after each 500 hr aging tests, the solar reflectance and emissivity on the coating surfaces of samples were examined. The solar reflectance and emissivity were carried out by means of spectrometer with integrating sphere, allowing characterizing the solar reflectance capability of the samples before and after the accelerated weathering tests. The solar reflectance and emissivity of samples are measured by using UV/VIS/NIR spectrometer and FTIR spectrometer based on ISO 9050 and 10292.

3. RESULTS AND DISCUSSION

Figure 1 to 3 show how the solar reflectance of 20 samples varied with time after 2000 hours weathering testing. All samples show reflectance reductions over time. During the first 500 hours there is a significant variability. The results of natural weathering testing indicated that the data after 500 hours are consistent with optical stability for these samples, with reflectance changes being due to dust accumulation in this study. It is because that Taiwan is located in the subtropical region with high temperature, humidity and high level of invisible pollutants such as dust and toxic aerosols in the air. After 2000 hours of natural weathering exposure the solar reflectance difference changed from 6.22 % to -11.62 % among white color samples, from -2.72 % to -4.20 % among grey color samples, from -0.75 % to -11.92% among green color samples, and from -3.57 % to -11.77 % among blue color samples. On the other hands, the results of two accelerated weathering tests indicated that there is no significant difference on solar reflectance with various colors of coatings.

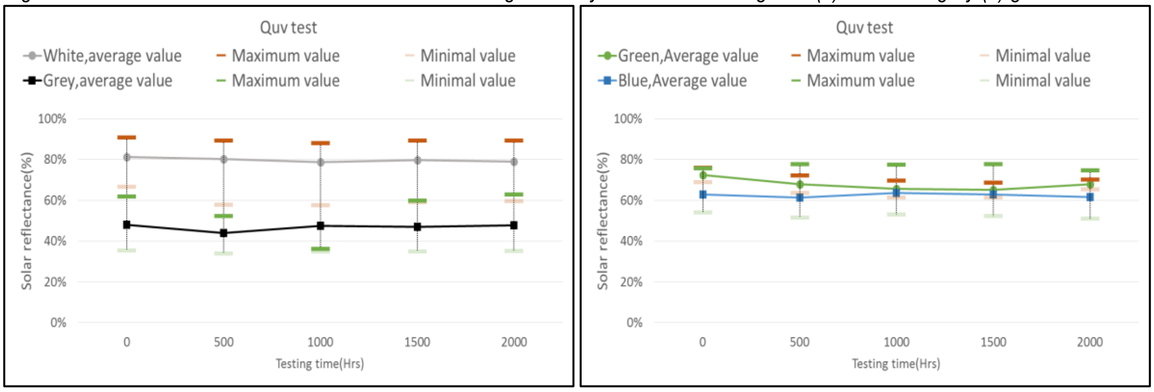
test conditions	CNS 15200 : Methods of test for paints − Part 7-5: Long-period performance of film − Natural weathering	CNS 15200: Methods of test for paints − Part 7-6: Long-period performance of film − Artificial weathering and exposure to artificial radiation(Exposure to filtered xenon-arc radiation)	CNS 1183: Laminated glass 7.3Radiation resistance test
Irradiance	-	290 nm-400 nm	295 nm-360 nm
Water quality	-	conductivity < 2 μS/cm, a residue on evaporation < 1 mg/kg	-
Operating mode	-	Continuous run	Continuous run
Air temperature	27.7 ˚C	38±3 ˚C	45±5 ˚C
Black panel temperature	-	63±2 ˚C	-
Relative humidity	75.7 %	40~60 %	-
Wetting time, min	-	(18±0.5) min	-
Dry period, min	-	102 min	-

Table 1: Accelerated outdoor weathering, Quv, xenon arc exposure test conditions



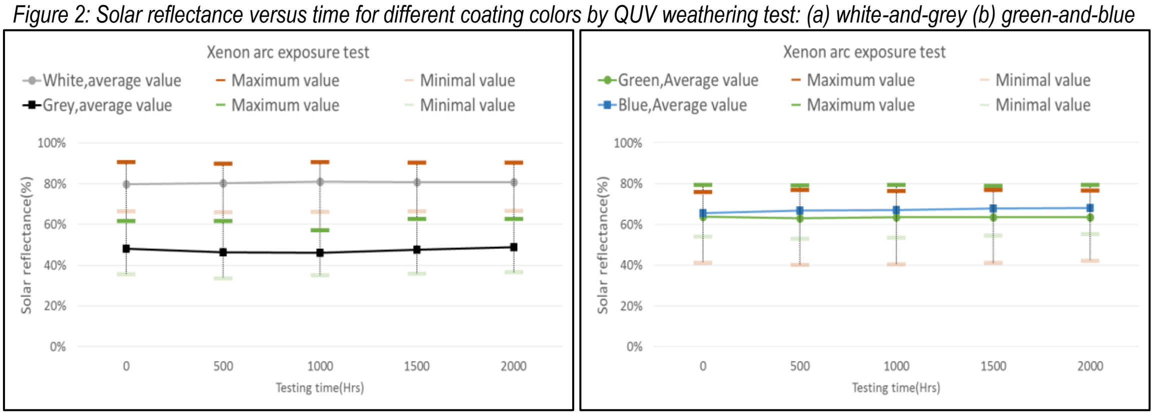
(a) (b)

Figure 1: Solar reflectance versus time for different coating colors by natural weathering test: (a) white-and-grey (b) green-and-blue



(a) (b)

Figure 2: Solar reflectance versus time for different coating colors by QUV weathering test: (a) white-and-grey (b) green-and-blue



(a) (b)

Figure 3: Solar reflectance versus time for different coating colors by xenon arc exposure test: (a) white-and-grey (b) green-and-blue

Figure 4 to 7 show the comparison between the solar reflectance and emissivity of samples before weathering test and those of after 2000 hours weathering test. The experimental results indicated that the difference between initial solar reflectance of steel plate samples and those after 2000 hours weathering test is in the range of ± 10%. The emissivity deviation of steel plate samples and cement brick is in the range of ± 2 % and ± 5 %, respectively. In the natural weathering test, the maximum and average attenuation rate of solar reflectance is 18.89 % and 8.38 % for steel plate specimens. The maximum and average attenuation rate of the solar reflectance for cement brick specimens is 22.3 % and 5.13 %, respectively. In addition, the specimen subjected to outdoor natural weathering could produce algae on the surface due to moisture in the atmosphere, will lead solar reflectance to be more significant for the decline, but emissivity will not be affected by the dust in the air. It is worth noting in this study that natural weathering test can reflect the effect of actual climate and solar radiation conditions on the thermal insulation properties degradation of coating materials. It usually takes more than 2 years to get the results, not only wasting time, but also the different testing sites will also cause significant differences.

In the cases of xenon arc exposure and QUV weathering test, the most samples declines in reflectance by only 1.43 % and 3.62 % over the 2000 hours period. The results have been shown in Fig. 5 and Fig. 7 indicated that thermal emissivity declines similar to solar reflectance, but the declines are smaller in magnitude. According to the statistics data of sunshine duration in Taiwan, the area with the largest daily solar energy intensity is Chiayi area, and the UVA energy accounts for 1.23 % of the total solar radiation energy. Thus, 266 hours UV accelerated aging test is approximately equal to 1 year of Taiwan UV radiation exposure. We can deduce that a sample subjected to 2660 hours in xenon test chamber or accelerated weathering QUV tester equals 10 years of outdoor exposure. However, many of the factors, such as temperature, humidity, solar radiation, climate and test material that affect the aging of the paint should be considered. It is theoretically impossible to have a single magic number that you can multiply by weathering tester exposure hours to compute years of outdoor exposure.

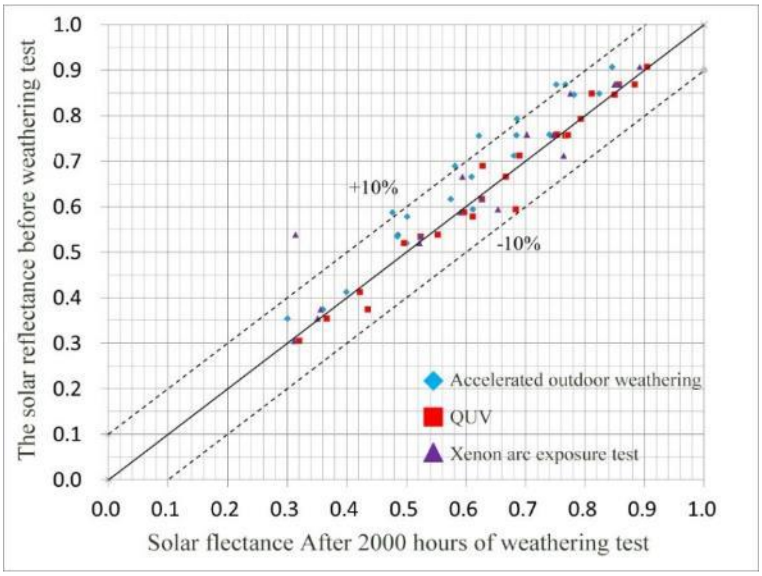


Figure 4: Comparison between the solar reflectance of samples before weathering test and those of after 2000 hours weathering test (steel plate)

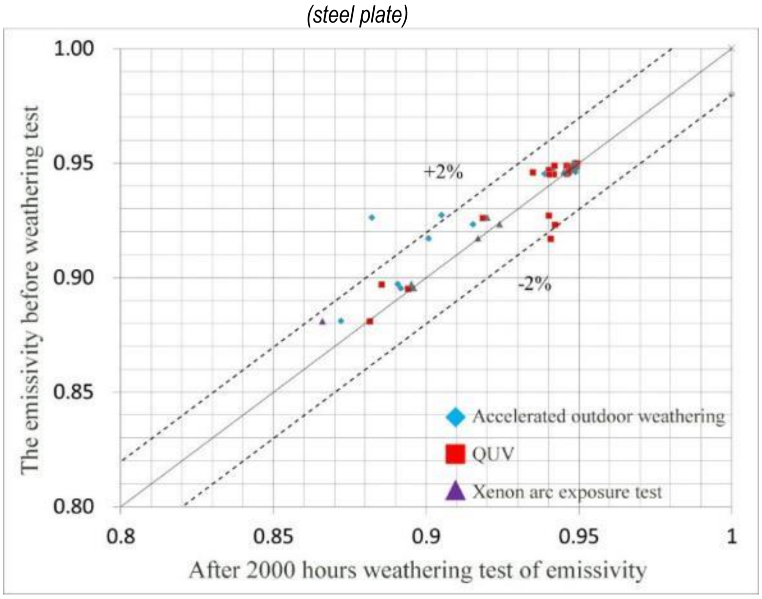


Figure 5: Comparison between the emissivity of samples before weathering test and those of after 2000 hours weathering test (steel plate)

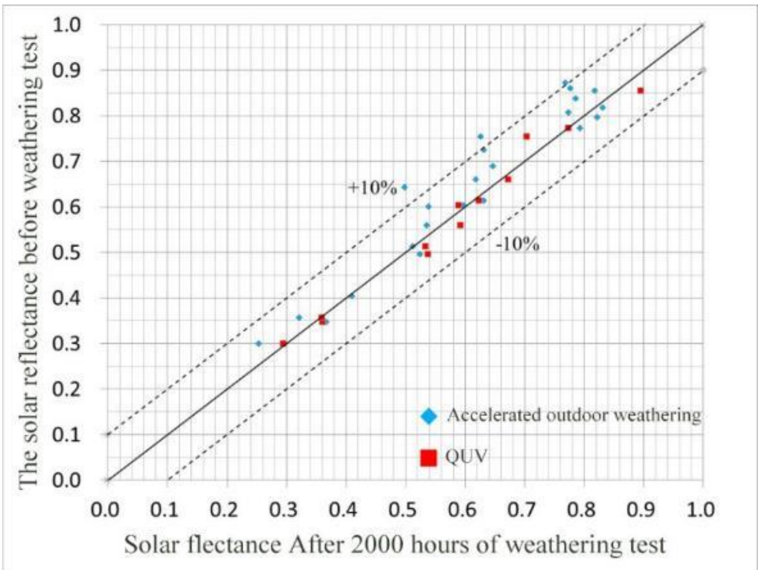


Figure 6: Comparison between the solar reflectance of samples before weathering test and those of after 2000 hours weathering test (cement brick)

4. CONCLUSION

In this study, 23 kinds of heat insulation paint on the market were selected to conduct the natural exposure testing and artificial accelerated aging testing, respectively, and the solar reflectance and emissivity of all samples were measured and compared. The research conclusions are described, as follows:

- The xenon arc exposure and QUV weathering test are suitable for evaluating the durability of paints in Taiwan. A sample subjected to 2660 hours in xenon test chamber or accelerated weathering QUV tester equals 10 years of outdoor exposure.
- In the natural weathering test, the average solar reflectance degradation are 8.38 % and 5.13 % for steel plate specimens and cement brick specimens, respectively. The specimen subjected to outdoor natural weathering could produce algae on the surface due to moisture in the atmosphere, will lead solar reflectance to be more significant for the decline
- In the cases of xenon arc exposure and QUV weathering test, the most samples declines in reflectance by only 1.43 % and 3.62 % over the 2000 hours period. The thermal emissivity declines similar to solar reflectance, but the declines are smaller in magnitude.

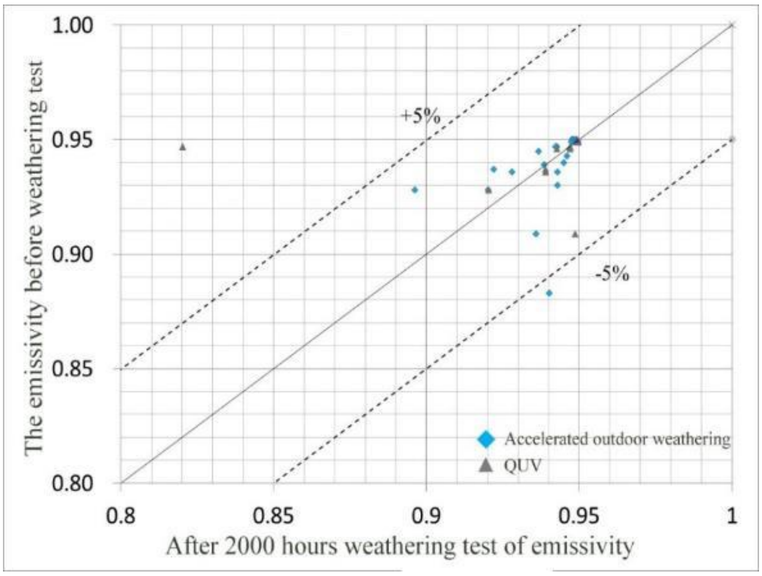


Figure 7: Comparison between the emissivity of samples before weathering test and those of after 2000 hours weathering test (cement brick)

ACKNOWLEDGMENTS

This study was supported by the Architecture and Building Research Institute, Ministry of the Interior of Taiwan under Projects PG10402-0042.

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