PERFORMANCE TESTING OF BIONIPERFORM COATING

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TABLE OF CONTENT

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EXECUTIVE SUMMARY

SV Nova Pt Ltd (the “Client”) is a local enterprise dealing with advanced protective coatings. Through its global partnership and continuous technology transfer, the Client aims to bring technically-proven and eco-friendly coating products to its customers.

The Client has engaged the services of the Centre of Innovation in Environmental & Water Technology, Ngee Ann Polytechnic (the “Consultant”) to carry out performance testing of a coating product named BioniPerform (the “Coating”) from its German partner Bioni CS GmbH. According to the manufacturer, the Coating is based on nanotechnology and is non-toxic as well as has the properties of anti-mould, low thermal conductivity, high sunlight reflectance, and high moisture resistance. The Consultant tested the Coating for its properties in roofing ferrocement protection and thermal insulation through the setup of two testing systems as follows:

a) Accelerated ageing system — The Coating on a ferrocement slab was subjected to accelerated aging conditions by exposing it continuously to simulated extreme weather conditions such as ultra violet (UV) light, high heat, water, and rainwater. The protection capability of the Coating was compared to that of a non-coated slab.

b) Thermal insulation testing system — The Coating was also exposed to simulated heat conditions to establish the differential temperature changes between a non-coated and coated slab and to determine the potential energy savings that could be achieved with the Coating.

The results showed that the Coating provided a protection and anti-ageing effect for ferrocement. It slowed down the cracking and erosion process of ferrocement under exposure to UV light, heat, water, and rainwater. In addition, the Coating exhibited good thermal insulation characteristic as it could significantly reduce the surface temperature of the ferrocement and the heat transfered through the ferrocement.

Based on the outcomes of this project, it is estimated that the Coating can reduce heat transfer by 266.8 W/m^2, and this will help to save the air conditioning electricity cost by \$34.4/m^2 per year.

1.0 Test Methodologies

1.1 Accelerated ageing system

The accelerated ageing system was set up using guidelines from ASTM G 154-06 [1]. The weathering conditions of water, rainwater, UV light, and infrared light were used to ascertain the effects of aging. The ferrocement slab was placed in an iron tray and rested on a 10 cm thick sponge to compensate for unevenness in the bottom of the slab and ensure that there is full contact with water during the testing. A 1 mm thick Coating was painted on a square-shaped corner of the slab whilst an identical square in the opposite corner was used as the control uncoated sample which will be subjected to the same test conditions. See Figure 1 for the setup.

Fig.1. Accelerated ageing system.

Two identical UV tubes (UVA-340, 15W)[1] with reflective covers were located 5 cm above the square zones in such a manner that both zones received uniform irradiance, as shown in Figure 1.

Two identical incandescent bulbs (500W) were supported 4 cm above the centers of the square zones respectively to provide the same radiative intensity to the zones. The surface temperatures were monitored by an infrared thermometer (Raynger ST6, Raytek).

The tray was filled with water and the water level was maintained so as to provide constant moisture to the slab. The sponge at the tray bottom helped to retain the water and prevent rapid evaporation and to render a complete contact between the water and the bottom of the slab. In addition, rainwater collected in the vicinity of the test site was sprayed every other day on the surfaces of the slab.

The total ageing cycle and duration was 9 hours per day for 25 days.

1.2 Thermal insulation testing system

This system comprised an open styrofoam box with the same size of a ferrocement slab, an incandescent bulb (500W), three thermocouples, two digital thermometers and a wooden enclosure. As shown in Fig.2, the non-coated ferrocement slab was placed in the styrofoam box, with an incandescent bulb fixed centrally at 5 cm above the slab surface. The sides of the slab were covered with styrofoam to prevent heat dissipation. The bulb heated up the surface and the heat was transferred into the styrofoam box by conduction, convection, and radiation through the slab. To measure the temperatures at the slab surface and inside the styrofoam box, one thermocouple was attached to the top surface at the center of slab and two thermocouples were placed at the center of the styrofoam box. During the test, the system was shielded by a wooden enclosure to prevent external disturbance. The real time temperature data was recorded by the digital thermometers. The sampling frequency was every 15 seconds and the test lasted for 2 hours.

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[1] *Fluorescent black lights, also known as UVA lamps, are available with peak emissions of 340nm-370nm (e.g. UVA-340 and UVA-351). For the UVA-340 lamp, the short wavelength irradiance is similar to direct solar radiation below 325 nm. The UVA-351 spectral distribution at lower wavelengths is similar to that of daylight filtered through window glass. Because the UVA lamps do not emit high energy radiation below the cut-off level for terrestrial solar radiation, correlation with outdoor weathering is good [2]. Therefore, UVA-340 tubes were selected as the UV source in this experiment to simulate direct sunlight as in actual usage of the slab.*

The same process was repeated using a coated slab which was painted with a 1mm thick Coating on the complete top surface. The temperature profiles of the two tests were plotted and analysed.

Fig.2. Thermal insulation testing system.

2.0 Results

2.1 Anti-ageing effect of the Coating

During the ageing test, surface temperatures at the centres of the two squares were periodically monitored by an infrared thermometer. The temperature of the coated zone was found to be always much lower than that of the non-coated one. In one instance, whilst the temperature at the centre of the coated zone was measured at around 130°C, that of the non-coated zone was found to be considerably higher at around 200°C. Taking into account the fact that the energy emitted by the incandescent bulbs was identical, this significant temperature difference must have been attributed to the thermal characteristic of the Coating, which probably either reflected part of the infrared energy from the slab or facilitated the heat dissipation from the slab.

After 25 days exposure in the accelerated ageing system, the ferrocement slab was removed for visual inspection. The appearance of the Coating had no significant change as shown in Fig.3 (a). The Coating was then removed using solvent and water to expose the ferrocement (Fig.3, (b)). The differences in morphology of the coated and non-coated zones are shown in Fig.3.

The two tested zones showed significant differences after ageing. As shown in Fig.3 (c), (d), (e), and (f), the area with Coating has a lighter color and a smoother surface than the area without Coating. These changes in coloration and surface texture are consequences of the erosion of cement caused by rainwater, UV light, and heat and the exposure of sand particles in the slab. It appears that the Coating can retard the surface erosion rate of the ferrocement. This observation supports its claim on waterproofing characteristic and resistance to surface temperature.

In addition, as shown in Fig.3 (e), (f), (g), and (h), the non-coated area exhibits some cracks in both the surface and the side of the slab, while the coated area has no visible crack. The cracks can be attributed to the effects of the cyclical thermal expansion and the erosion of cement. As the Coating can tolerate high surface temperatures and consequently protect the internal area of the ferrocement slab from temperature effects, it is likely that it can also reduce the thermal expansion damage and prevent cracking.

(a) Coating after ageing

(b) After removal of Coating

(c) With Coating

(d) Without Coating

Closed up views

(e) With Coating

(f) Without Coating

(g) With Coating

(h) Without Coating

Fig.3. Morphology of the ferrocement slab after ageing.

2.2 Thermal insulation function of the Coating

a) Temperature difference of the slab top surface

Fig. 4 shows the temperature profiles of the slabs with and without Coating under the same intensity of heat exposure. The temperatures of the slab with Coating are consistently lower than that of the slab without Coating.

The temperature differences at the initial stage are between 40°C and 50°C, and it reduced when the heating continued. This phenomenon indicates that the coating has either a low emissivity value or high reflective index, which caused the dissipation of radiated heat to the surrounding. Therefore the surface absorbed less heat and the temperatures of the slab were lower.

An explanation for the graduating decrease in temperature changes could be that the dissipated heat was trapped by the enclosure and hence this retained heat probably heated up the slab surface again by means of radiation, conduction and convection.

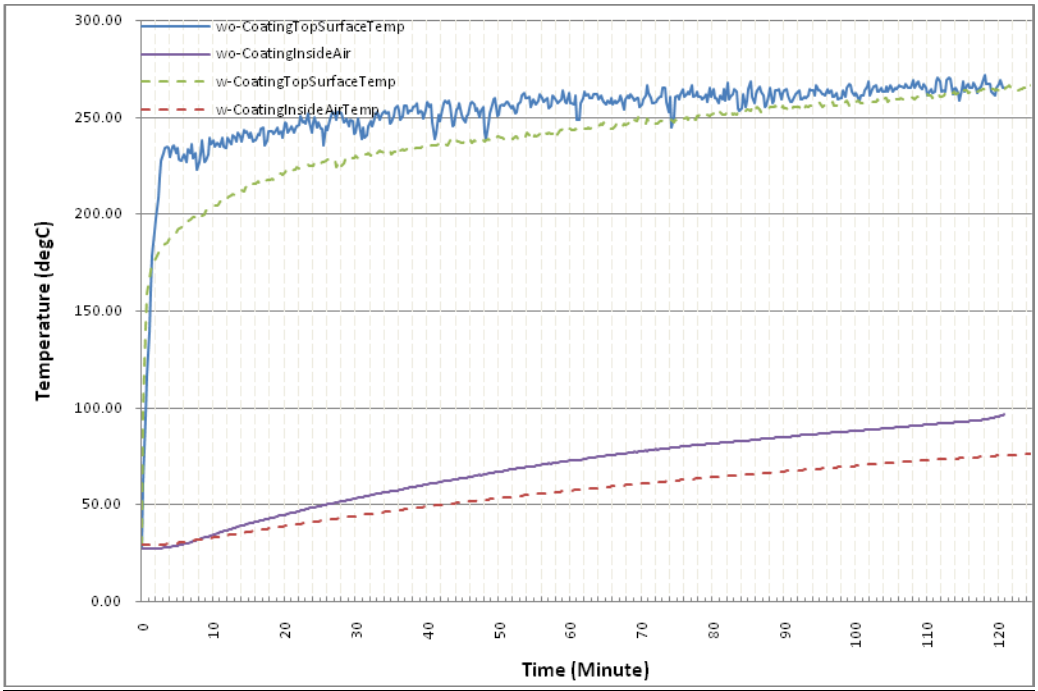

Fig. 4. Temperature profiles of the top surface and the air inside the Styrofoam box.

b) Temperature difference of the air inside the styrofoam box

The variations of the air temperatures inside styrofoam box are represented by the purple and dotted red lines in Fig.4 for the test period of 2 hours. As can be seen from the graphs, the air temperatures of the slab with Coating not only depicted a lower rate of increase, but are consistently lower than that of the slab without Coating. This suggests that the rate of heat transfer through the coated slab was slower and demonstrates that the Coating clearly provided a better thermal insulation.

c) Energy Saving Estimation

Rate of Heat Flow From external to internal areas:

$$\dot{Q} = \frac{m\,C\,(T_2 - T_1)}{t} \qquad \text{.....................} \ (1)$$

where

$\dot{Q}$ is the rate of heat flow

m is mass of air inside the insulated box

C is the specific heat of air (1.02 kJ/kgK)

T_2, T_1 are the final and initial temperature of air of the period

t is the time takes for the temperature change

The rates of heat flow through the slabs were computed using the same 1-hour time zone from 0 min to 120 min. The mass of air was calculated based on the internal dimension of the styrofoam box as in Fig. 5.

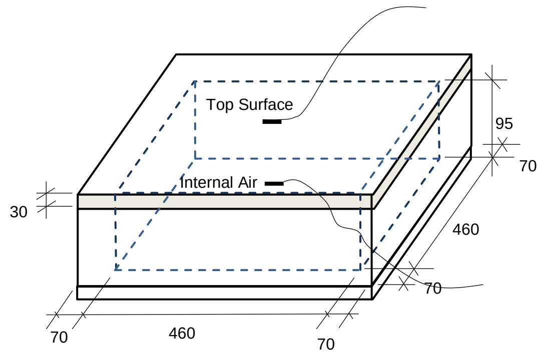

Fig. 5. Dimensions of the Styrofoam box for the test.

Mass of air = Internal volume of the box × air density
= 0.46m x 0.46m x 0.095m x 1.2 kg/m^3
= 0.02412 kg

The heat flow rates for both slabs are tabulated as follows:

	Without Coating	With Coating
Heat Flow Rate $\dot{Q}$	0.02412×1020×(96.5-27.2) /(120×60) = 0.2368 W	0.02412×1020×(76.5-27.2) /(120×60) = 0.1685 W

A very rough estimation of energy saving due to this reduction of heat gain from roof slab for an apartment with 100 m^2 air-conditioned space is calculated as follows:

<table>
<tr><th></th><th>Without Coating</th><th>With Coating</th><th>Reduction of Heat Gain</th></tr>
<tr><td>Heat Flow Rate $\dot{Q}$</td><td>0.2368 W</td><td>0.1685 W</td><td>0.2368 – 0.1685 = 0.0683 W</td></tr>
<tr><td>Heat Flow Rate Per unit Area</td><td>0.2368/(0.016×0.016)= 925 W/m2</td><td>0.1685/(0.016×0.016) = 658.2 W/m2</td><td>925 – 658.2 = 266.8 W/m^2</td></tr>
<tr><td colspan="4">The above reduction was based on the surface temperatures of 200°C and above. Note that the heat transfer area was assumed to be a square area with edge length equal to the diameter of the bulb.</td></tr>
<tr><td colspan="4">Considering a top floor apartment of 100 m^2.
Reduction of heat gain = 266.8 x 100 = 26680 W</td></tr>
<tr><td colspan="4">Assuming an average 4 hours hot and sunny period each day, 365 days a</td></tr>
</table>

year, Reduction of heat gain = 26680 x 4 x 365 = 38952800 Wh (38952.8 kW)
Using SS530:2006 Code of Practice for Energy Efficiency Standard for Building Services and Equipment, the baseline coefficient of performance (COP) for an air-cooled split type air-conditioning unit is 2.49. Annual electrical energy saving = 38952.8 / 2.49 = 15643.7 kWh
SP Services December 2009 electricity rate = 22 cents per kWh Annual electricity cost saving = 15643.7 x 0.22 = $ 3442

3.0 Conclusions & Recommendations

(1) The Coating provided a protection and anti-ageing effect for ferrocement. It prevented ferrocement from cracking and erosion under exposure to UV light, heat, water, and rainwater.

(2) The Coating exhibited a good thermal insulation property. It can significantly reduce the surface temperature of the ferrocement and the heat transfer through the ferrocement.

(3) As a very rough estimation, the Coating can reduce heat transfer by 266.8 W/m^2, which can save air conditioning electricity cost by $\$34.4/m^2\cdot year$.

Due to the constraints in the work scope of the project, the test only measured limited parameters as agreed with the Client. As such, some assumptions had to be made to obtain the estimated cost saving in energy. Therefore, it is strongly suggested that the results should be used with caution. A more thorough study will be required for more accurate results.

References

[1] ASTM G 154-06 (Standard practice for operating fluorescent light apparatus for UV exposure of non-metallic materials).

[2] Rudy Leber. Laboratory weathering devices. Environmental Technology, 1 (2002), p9.

List of Figures