Study on the Aging Properties of a Viscoelastic Protective Material for Concrete

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ABSTRACT: The aging properties of the protective material are of great importance to ensure the safe operation of the concrete structure during its service life. In this study, the aging properties of a viscoelastic protective coating were investigated. The mechanical properties of the coating under outdoor exposure and high-low temperature cycles were determined. Fourier Transform Infrared Spectroscopy (FTIR) was used to observe the change of chemical structure after aging test. The results show that the tensile strength, the elongation at break and the tear strength decrease by 2.33%, 26.58% and 1.63% respectively after 150 days of natural exposure. The tensile strength, the elongation at break and the tear strength decrease by 32.49%, 39.11% und 30.44% respectively after 100 times of high-low temperature cycles. The natural exposure affects the elongation at break of the coating most, while the high-low temperature cycles have a significant effect on the tensile strength, the elongation at break and the tear strength. FTIR analysis shows that the chemical bonds on the surface of the material are degraded because of natural exposure.

KEYWORDS: aging properties, mechanical properties, outdoor exposure, high-low temperature cycles

INTRODUCTION

To ensure the safe operation of concrete infrastructures during its service life, a wide range of methods are applied to protect the concrete structure from degradation and failure. Corresponding to different aggressive agents, polymer-modified cementitious mortars, protective jackets, corrosion inhibitors, sacrificial anodes, organic coatings, biofilms and many other options can be adopted to protect concrete structures (Baltazar, Santana, Lopes, Correia and Rodrigues, 2014; Pailes, Brown, and Sharp, 2012; Zhang, Yao and Wang, 2012; Almusallam, Khan, Dulaijan and Al-Almoudi, 2003; Bertolini and Redaelli, 2009; Kondratova, Montes and Bremner, 2003; Soleimani, Ormeci and Isgor, 2013; Alhozaimy, Hussain, Al-Zaid and Al-Negheimish, 2012; Chai, Zhu, Yi, Zhang, Wang, Fang, Bai, Cui and Shao, 2015; Eymard, Plassiard, Perrotin and Le Fay, 2015; Medeiros and Helene, 2009; Villagrán Zaccardi, Bértora and Di
Maio, 2012). Among above methods, coating is considered to be one of the most effective surface treatments.

There has been an amount of studies focused on the influence of adverse experimental circumstance on properties of concrete coated with various coatings. Sun et al. utilized a layered and staggered covering to protect concrete against a 12.7mm armour-piercing incendiary projectile at velocities ranging from 537.7 to 596.5 m/s and found that the protected concrete targets exhibited no damage on the distal surface, whereas the unprotected concrete targets were fractured with penetrating cracks throughout the thickness of the target (Sun, Yu, Wang and Liu, 2015). Wei Wang et al. applied a silicone material on concrete sampling and found it improved the resistance to chloride penetration when compared to the non-protected concretes. (Wang, Li, Wang, Wang, Li and Tian, 2014) Previous studies show that coatings can improve the substrate's resistance to both physical damage and chemical corrosion.

To take full advantage of the protective properties, the coating should have good mechanical properties and high resistance to corrosive mediums. Both the physical structure and the chemical structure of the coating should be capable of keeping stable in varying weather conditions. In previous studies, to investigate the aging properties of coatings, accelerated aging tests are used. Wei Wang et al. evaluated the aging property of the silicone material by the test of water absorption after 1000h xenon lamp aging and the result showed the material has excellent anti-aging performance. Ping Lu et al. conducted a series of accelerated aging tests on polyaspartic ester based polyurea and the results show that the resistance of this coating to salt-spray and dry-wet circulation was excellent, but the resistance to corrosion decreased under the co-action of UV and salt-spray (Lu, Huang, Shi and Zhu, 2010; Lu, Chen, and Huang, 2007).

In this study, the aging properties of a novel viscoelastic protective coating were investigated. Mechanical properties, such as the tensile strength, the tear strength, the elongation at break, and the hardness, are determined under 150d natural exposure and 100 times of high-low temperature cycles respectively. FTIR analysis was carried out on the coating before and after 150d natural exposure.

**EXPERIMENTAL WORK**

In the study, the two components to prepare polyurea are provided by Qingdao Shamu International Co., Ltd.). To prepare the coating for outdoor exposure test and high-low temperature cycling test, a GX-8 spray gun and a PHX-20 spray machine were employed and PVC plates with the size of 90×120 were utilized as the molds. Under 23℃ and 50% RH, the viscoelastic protective coatings were prepared by spraying the two components (mixed with the mass ratio 11:10) on the surface of the PVC plates. The thickness of the coatings was controlled at 2mm. After 148h, the coatings were taken off from the molds.
To study the effect of different environment on mechanical properties of the coating, two experimental conditions - the outdoor exposure and the high-low temperature cycles - are prepared. The natural exposure test and the high-low temperature cycling test were conducted according to the standard GB/T 16777-2008 (building waterproof coating test method).

After 20d, 40d, 60d, 100d, 120d and 150d natural exposure, standard dumbbell-shaped and hump-shaped specimens were prepared and the tensile strength, the elongation at break, the tear strength and the hardness of them were measured with universal testing machine model MZ-4102.

The method for high-low temperature cycle is as follows: 1) placing the samples in -30℃ refrigerator for 4h; 2) taking the samples out and put them at room temperature for 1 h; 3) keeping the samples in 80 ℃ for 4 h; 4) moving the samples at room temperature for 1 h. After 20 times, 40 times, 60 times and 100 times of high-low temperature cycles, the tensile strength, the elongation at break, the tear strength and the hardness of them are measured respectively.

RESULTS AND DISCUSSIONS

Influence of the Outdoor Exposure

Under the natural exposure, the sunshine, the moist, the wind, the dust and the varying temperature would have a mixed effect on the coating. To measure this influence, the mechanical properties after 20d, 40d, 60d, 100d, 120d and 150d of exposure are determined and shown in Table 1.

It can be seen that from Table 1, the tensile strength is 10.28MPa at the beginning, decreasing to the minimum value, 9.46MPa, after 100d of exposure, and then increasing to 10.04MPa after 150d of exposure. The maximum decline rate and the decline rate after 150d is 8.0% and 2.3%, respectively. The elongation at break decreases from 378.40% to 277.84% and the decline rate is 26.5% after 150d. The tear strength is around 34 N/mm from 0d to 150d and the hardness of the coating shows 4.7% increase after 150d.

Table 1. Mechanical properties before and after exposure

<table>
<thead>
<tr>
<th>Exposure duration (d)</th>
<th>Tensile strength (MPa)</th>
<th>Elongation at break (%)</th>
<th>Tear strength (N/mm)</th>
<th>Hardness (Shore A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.28</td>
<td>378.40</td>
<td>34.95</td>
<td>85</td>
</tr>
<tr>
<td>20</td>
<td>10.21</td>
<td>365.46</td>
<td>34.40</td>
<td>83</td>
</tr>
<tr>
<td>40</td>
<td>9.91</td>
<td>355.19</td>
<td>33.60</td>
<td>85</td>
</tr>
<tr>
<td>60</td>
<td>9.53</td>
<td>346.70</td>
<td>34.07</td>
<td>89</td>
</tr>
<tr>
<td>100</td>
<td>9.46</td>
<td>321.58</td>
<td>33.45</td>
<td>89</td>
</tr>
<tr>
<td>120</td>
<td>9.75</td>
<td>280.44</td>
<td>34.14</td>
<td>87</td>
</tr>
<tr>
<td>150</td>
<td>10.04</td>
<td>277.84</td>
<td>34.38</td>
<td>89</td>
</tr>
</tbody>
</table>
Influence of the High-low Temperature Cycles

To study the effect of alternating temperature change on the properties of the materials, high-low temperature cycling experiments were carried out to accelerate the aging of the materials. The mechanical properties were tested after 20, 40, 60 and 100 aging cycles respectively and the results are shown in Table 2.

<table>
<thead>
<tr>
<th>Cycling times</th>
<th>Tensile strength (MPa)</th>
<th>Elongation at break (%)</th>
<th>Tear strength (N/mm)</th>
<th>Hardness (Shore A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.28</td>
<td>378.4</td>
<td>34.95</td>
<td>85</td>
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<tr>
<td>20</td>
<td>7.95</td>
<td>336.63</td>
<td>31.13</td>
<td>78</td>
</tr>
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<td>40</td>
<td>7.94</td>
<td>303.93</td>
<td>30.25</td>
<td>75</td>
</tr>
<tr>
<td>60</td>
<td>7.07</td>
<td>256.59</td>
<td>26.69</td>
<td>74</td>
</tr>
<tr>
<td>100</td>
<td>6.94</td>
<td>230.42</td>
<td>24.31</td>
<td>72</td>
</tr>
</tbody>
</table>

As it can be found in Table 2, the tensile strength, the elongation at break, the tear strength and the hardness all show a downward trend after high-low temperature cycles. Before the cycling experiment, the tensile strength, the elongation at break, the tear strength and hardness are 10.28MPa, 378.4%, 34.95N/mm and 85 respectively. After 100 times of high-low temperature cycles, the decline rates are 32.49%, 39.11%, 30.44% and 15.29% respectively. The results show that dramatic temperature changing may have a significant influence on the mechanical properties, especially the elongation at break.

It is shown from Table 1 and Table 2 that the elongation at break is the most vulnerable factor to outdoor environment and dramatic temperature changing.

**FTIR Microscopic Analysis**

In order to study the relationship between the microstructure and the mechanical properties, FTIR analysis was carried out on original samples and samples after 150d natural exposure. The FTIR spectra of the samples before and after the treatment are shown in Figure 1.

As it can be seen, before outdoor exposure, the absorption peaks near 3360 cm\(^{-1}\) and 2966.38-2871.87 cm\(^{-1}\) refer to the N-H stretching vibration peak and the C-H (\(-\text{CH}_3\) and \(-\text{CH}_2\)) stretching vibration respectively. Moreover, the peaks in 1600.84cm\(^{-1}\), 1701.13cm\(^{-1}\) and 1531.41cm\(^{-1}\) is the result of mixed contribution of the C=O stretching, the C-N stretching and the N-R deformation vibrations. The peak around 1100cm\(^{-1}\) is for the C-O-C stretching vibration. After 150d of outdoor exposure, the peaks mentioned above are weakened, indicating the bonds are disrupted. In outdoor environment, the coating is exposed to the combined effect of moist, wind, dust and sunshine and the
surface chemical bonds are disrupted, leading to a decline in mechanical properties.

Figure 1. The infrared spectrogram of protective material before and after 150d of outdoor exposure.

CONCLUSION

In this study, the mechanical properties of a viscoelastic protective material under the outdoor exposure and high-low temperature cycles were investigated. The FTIR analyses of the coating surface before and after outdoor exposure were conducted. The results show that, under outdoor exposure, the elongation at break reaches the highest value with 26.5% drop after 150d. Under high-low temperature cycles, the tensile strength, the elongation at break, the tear strength and the hardness decrease by 32.49%, 39.11%, 30.44% and 15.29%, respectively. The FTIR analyses indicate the presence of N-H, C-H, C-N, C=O and C-O-C. The chemical bonds are weakened after 150d of outdoor exposure. The deterioration of the coating possibly is caused by the disruption of the chemical bonds under the experimental environment.

ACKNOWLEDGEMENT

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REFERENCES


