Performance Study Research of New Maintenance Method in Airport Pavement Concrete of China

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Abstract: Through comparing actual projects this paper presents and discusses the effects of curing film and geotextile on the mechanical properties, durability and pore structure of concrete. The results show that, compared with the maintenance of geotextile, the curing film can enhance the strength of concrete to a certain extent, improve frost resistance and optimize pore structure of concrete.

1. Introduction
In concrete construction project of airport pavement, concrete maintenance is a sub-project which takes the longest time and has great impact on concrete quality[1]. Generally speaking, the starting time of concrete maintenance should be determined according to the local climate conditions and the types of cement used in concrete projects[2]. China's airport pavement concrete mainly uses dry-hard concrete whose cementitious material is relatively less[1]. The concrete usually begins to be cured about 24 hours after concrete pouring then the maintenance will at least last 14 days[1,3,4]. At present, the maintenance of airport pavement concrete generally adopts several methods, such as sprinkler natural maintenance, spray film maintenance and plastic film wrapping maintenance[1]. The mechanism of these methods is to keep concrete wet and avoid water loss in order to achieve the maintenance purpose[2]. Currently, sprinkler natural maintenance is mostly used in China’s airport projects, mainly covering concrete with straw curtain, and frequently sprinkling water to keep wet[5]. For this method in water-rich areas it may not be a big problem, but in the arid regions of China, the scarcity of water resources will have a negative effect on the cost and quality of pavement concrete construction project of airport. The current research mainly focuses on the influence of curing on shrinkage and deformation[6,7,8,9], the influence of admixtures such as slag and fly ash on concrete curing[10,11], the impact of curing on cement hydration[12], the influence of curing under laboratory conditions on SCC[13], the influence of curing on the bond between cement and admixtures[14] and so on. For the actual engineering site, the comparison of different conservation modes maintaining airport dry hard concrete and their internal structure analysis are rarely involved. This paper mainly based on the actual engineering environment compares the mechanical properties, durability and pore structure of concrete between the widely used geotextile maintenance method and the new curing film maintenance method, and provides engineering application and technical reference for the curing of dry-hard concrete in arid and water-deficient area.

2. Experimental procedure
The Water-saving moisturizing curing film (hereinafter referred to as the curing film) shown in figure 1(a)-(c) is based on a novel water-absorbing polymer material, and a plastic film (including a mask film and a base film) as a carrier adheres to the composite. The mask film has tensile strength and water retention, and the base film is an ultra-thin plastic film, which has water permeability because of pervious orifice in it.

The polymer material can absorb 200 times of its own weight of water, expand into transparent lens, and turn liquid water into solid water, and 0.4-0.6 kg water per square meter of curing film can be stored, resulting it becoming a solid micro-reservoir.

By capillary action, water penetrates into concrete surface through the pervious orifice of base film, and meanwhile it continuously absorbs the hot evaporated water of concrete during the hydration process, so the concrete surface can always remain wet during a curing period.

3. Results and analysis

3.1 Strength

After wet maintaining of 14 days with curing film and geotextile, then natural curing to 28 days age, airport pavement concrete under two curing modes are cut on site to form the specifications of 150 x 150 x 550 mm to test its flexural strength which data is as shown in figure 2. The results show that after 7 days of maintenance with geotextile and curing film the average flexural strength of airport pavement concrete is 4.4 MPa and 4.1 MPa, respectively. And after maintaining of 14 days the average flexural strength is 5.8 MPa and 5.5 MPa. Therefore, for 7 and 14 days of flexural strength, the curing film is 6.7% and 5.8% larger than geotextile, respectively. With concrete reaching 28 days age, the flexural strength of airport dry-hard concrete cured with curing film and geotextile is 6.4 MPa and 6.0 MPa, respectively, which means the flexural strength of concrete cured with curing film is about 6.7% higher than that of geotextile.

Therefore, from the comparison of mechanical properties such as flexural strength, it can be seen that the curing film and the existing construction methods of geotextile can meet the requirement of mechanical properties in the current standards (flexural strength of 28 days > 5 MPa)[8,9,28], and compared with the maintenance methods of geotextile, the curing film has more advantages in
improving the mechanical properties of concrete. Appropriate wet curing is conducive to the strength growth of concrete[15,16]. The possible reason is that good curing is conducive to the hydration of concrete, and promotes the concrete structure to be more compact, which is confirmed in the following study of point analysis.

Figure 2. Flexural strength of concrete with two ways of curing (°C)

3.2 Frost resistance
The mass loss rate of concrete pavement concrete with the freeze-thaw cycle is shown in figure 3. During the 300 freeze-thaw cycles[3], as the number of freeze-thaw cycles increases, the mass loss rate of airport pavement concrete corresponding to the two maintaining methods shows an increasing trend. Fit the two, the equations are as follows:

Curing film:  
\[ y = 1.53 \times 10^{-3} x - 3.84 \times 10^{-2}, R^2=0.97 \]  
(1)

Geotextile:  
\[ y = 1.94 \times 10^{-3} x - 4.95 \times 10^{-3}, R^2=0.98 \]  
(2)

It can be seen from the fitting equation that the mass loss rate of concrete under the two maintaining modes increases almost linearly, and the mass loss rate of curing film is less than that of geotextile at any time. After 300 freeze-thaw cycles, the mass loss rate of both is far less than 5%, and the concrete mass loss rate with curing film and geotextile is less than 0.5% and less than 0.7%, respectively.

Figure 3. Temperature difference between geotextile and environment with 7-14 d (°C)

Figure 4. Law of relative dynamic elastic modulus of two conservation methods
Figure 4 shows the variation of relative dynamic elastic modulus of airport pavement concrete with freeze-thaw cycles. Fit them and the equations are as follows:

Curing film:

\[ y = 8.02 \times e^{-7x^2} - 0.04x + 99.53, \quad R^2=0.98 \]  

(3)

Geotextile:

\[ y = 2.40 \times e^{-5x^2} - 0.05x + 100.42, \quad R^2=0.99 \]  

(4)

During the 300 freeze-thaw cycles, the relative dynamic elastic modulus of concrete maintained by the curing film is always smaller than that of the geotextile. After 300 freeze-thaw cycles both of them are far greater than 60%, and for the curing film and geotextile they are greater than 92% and 86%, respectively.

For the curing film the relative dynamic elastic modulus is hardly lost in the 0-50 freeze-thaw cycles, and in 50-75 freeze-thaw cycles, the relative dynamic elastic modulus value has a large decrease, from 99.5% to 96.7%, indicating that the concrete deterioration rate characterized by relative dynamic elastic modulus is significant in the 50-75 freeze-thaw cycles. But then in the 75-300 freeze-thaw cycles, the relative dynamic modulus value decreases slowly and its slope is small, which means that the concrete degradation rate slows down. After 300 freeze-thaw cycles, the relative dynamic elastic modulus is still high, exceeding 92%. While for the concrete maintained by geotextile, its dynamic elastic modulus drops by about 6% in the 0-200 freeze-thaw cycles. From 200 to 250 cycles, within the 50 freeze-thaw cycles, the relative dynamic elastic modulus drops rapidly by about 6%, and after 300 freeze-thaw cycles it finally decreases to about 87%.

The relative dynamic elastic modulus and mass loss rate are important indicators for characterizing frost resistance of concrete. For the mass loss rate of concrete, the curing film is smaller than the geotextile during each freeze-thaw cycle, and for the relative dynamic elastic modulus, the curing film is larger than the geotextile in each freeze-thaw cycle. Therefore, it can be considered that the durability of concrete cured by curing film is better than that of geotextile. The main reason for this phenomenon may be that the internal structure of airport pavement concrete maintaining with curing film is more reasonable, and the pores with external through-holes are relatively small, mostly being internal closed pores, so that there are fewer channels for external water molecules to enter concrete interior during freeze-thaw cycles; in addition, the pores of concrete maintained by the curing film are smaller, the capillary pressure is greater, and the external moisture is more difficult to penetrate.

### 3.3 Pore analysis

As shown in figure 5 and table 1, the volume of harmless pore (<20nm) and less harmful pore(<20-50nm) per unit mass for the concrete covered by curing film is larger than that of geotextile, and the volume of harmful pore (50-200 nm) and more harmful pore (>200 nm) per unit mass for the concrete covered by curing film is less than that of geotextile. Meanwhile, the total porosity of airport pavement concrete maintained by curing film is less than that of geotextile, and compared with geotextile curing, the total porosity of concrete maintained by curing film decreases by about 5%.

The possible reasons for this phenomenon are as follows: in the process of maintaining period, because the curing film has a strong water-retaining capacity, the concrete surface covered by the curing film forms a wet curing environment. With the continuous hydration of cement, the free water in concrete is consumed a lot, and the surface humidity of concrete decreases. At this time, the curing film’ macromolecule material close to the surface of concrete begins to release the absorbed water, supporting the maintaining humidity of concrete, and the absorbed water is able to infiltrates continuously into the concrete through capillary, so as to promote the hydration of cement more fully. But for concrete adopting the geotextile maintenance method the moisture loss of its surface is relatively fast, and the cement in concrete is less hydrated.

On the other hand, the humidity change in the curing film does not show obvious repeated fluctuations and is roughly a continuous trend, which is unmatched by geotextile. For the maintenance of geotextile, the humidity is very high when the water is poured, because of the humidity difference between the geotextile and the outside air, and there is no measure to prevent its own water
evaporation, the humidity in the geotextile is quickly lowered, and some heat is taken away. Repeating this process for the next watering will not only cause a certain degree of dry-wet cycle, but also reduce the temperature during curing, which is not conducive to cement hydration[17].

In general, compared with the geotextile, the curing film can stably retain very high temperature and humidity with maintaining concrete, which is propitious to the smooth progress of hydration reaction of cementitious materials in concrete[18].

As a result, the porosity of some harmful pore (50-200 nm) and more harmful pore (> 200 nm) with larger pore size is obviously reduced, and some of them are transformed into harmless pore (< 20 nm) and less harmful pore (20-50 nm), and the total porosity of concrete decreases with the increase of cementitious products.

Figure 5. Pore size distribution histogram

Table 1. Sub-porosity(%)  

| Maintenance mode | Harmless pore (<20nm) | Less harmful pore (20-50nm) | Harmful pore (50-200nm) | More harmful pore (>200nm) | Total porosity |
|-------------------|-----------------------|-----------------------------|-------------------------|---------------------------|---------------|
| Curing film       | 8.97                  | 4.51                        | 1.46                    | 2.02                      | 16.96         |
| Geotextile        | 8.64                  | 4.42                        | 1.78                    | 2.48                      | 17.32         |

4. Conclusions
With concrete being 28 days age, the flexural strength of airport dry-hard concrete maintained by curing film and geotextile is 6.4 MPa and 6.0 MPa, respectively, which means the curing film is about 6.7% higher than the geotextile.

In freeze-thaw cycle process, for the concrete mass loss rate the curing film is smaller than the geotextile, and for the relative dynamic elastic modulus the curing film is larger than the geotextile. Therefore, it can be considered that the durability of concrete maintained by curing film is better than that of geotextile curing. The main reason for this phenomenon may be that the internal structure of airport pavement concrete maintaining by curing film is more reasonable, and the external through-pores are relatively few, mostly being internal closed pores, so that there are fewer channels for outside water to infiltrate the concrete interior during freeze-thaw cycles; in addition, the aperture of concrete maintained by the curing film are smaller, the capillary pressure is greater, and outside water is more difficult to penetrate.

The volume of harmless holes (<20nm) and less harmful pore (<20-50nm) per unit mass for the curing film is larger than that of geotextile, and the volume of harmful pore (50-200 nm) and more harmful holes (>200 nm) per unit mass for the curing film is less than that of geotextile. Meanwhile, the total porosity of airport pavement concrete maintained by curing film is less than that of geotextile,
and compared with geotextile curing, the total porosity of concrete maintained by curing film decreases by about 5%.

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