Application of anticoagulant ice microcapsule material in micro-surfacing technology

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Abstract—In order to solve the problem of road icing on vehicle driving safety in winter, a non-chlorine environmental protection anticoagulant ice microcapsule material is proposed in this study. It is a multi-core microcapsule structure composed of capsule core and capsule wall. The particle size is less than 0.075mm. It has good chemical stability, good mechanical properties and slow-release effect. When applied to the road, it will not affect the quality of road engineering. Based on the design concept of traditional salt storage pavement, the non-chlorine environmental protection anticoagulant ice microcapsule material is combined with micro surface treatment technology, and the micro surface compound application technology suitable for the special service environment of pavement in freezing area is designed and studied. The main results are as follows: (1) the ice coagulation effect of anticoagulant ice microcapsule materials is tested by sponge ice melting test and ice layer adhesion test. The test results show that anticoagulant ice microcapsule materials have significant ice anticoagulant effect, and are better than salt storage anticoagulant ice materials. (2) Through the road performance analysis of the micro surface, the anticoagulant ice microcapsule material has a certain impact on the cohesion and wet wheel wear of the slurry mixture, but they all meet the specification requirements. (3) The material is used in surface preventive maintenance technologies such as micro surfacing. It has excellent low-temperature snow melting ability, sustainable slow-release effect, excellent road performance and environmental protection.

1. Introduction
Rainy and snowy weather in winter has become one of the serious threats to traffic safety in most areas of North and southwest China [1], and the adhesion of frozen ice to the road surface will seriously reduce the skid resistance of the road surface [2]. The mature active anticoagulant ice technology in the market is still the anticoagulant ice material mainly composed of slow-release salinates, which is mainly divided into three categories [3]: the first category is chloride type, and the most commonly used industrial salt NaCl. The second type is the mixed type, including the mixing of chloride salt and non-chlorine salt, and the mixing of chloride salt and non-chlorine salt plus rust inhibitor [4]. The third type is non-chlorine type, and the most commonly used are polyols, CMA (calcium acetate) and potassium acetate [5]. Combine the anticoagulant ice materials with road construction technology to achieve the role of active anticoagulant ice on the pavement [6]. The most common is to add anticoagulant ice material to hot mix asphalt mixture and pave it on the pavement in advance. It can actively melt ice and snow in rainy and snowy weather in winter and reduce the impact of snow melting agent on the environment [7]. Its disadvantage is that the amount of anticoagulant ice agent is large, resulting in high material cost of anticoagulant ice agent [8]. Some researchers have also proposed other construction technologies as the carrier to combine the micro surface treatment...
technology of anticoagulant ice agent, which can obtain relatively long-lasting anticoagulant ice effect, better anti sliding performance and water sealing performance. At the same time, the material cost is significantly lower than that of anticoagulant ice covering technology[9].

To sum up, a non-chlorine environmental protection and slow-release anticoagulant ice material prepared by microcapsule technology is studied in this paper. The non-chlorine environment-friendly anticoagulant ice microcapsule material is combined with the micro surface treatment technology, which has good compatibility. The mixture performance, anticoagulant ice performance and road performance of the anticoagulant ice micro surface are analyzed, and the micro surface suitable for the special service environment of pavement in the freezing area is designed and studied.

2. Anticoagulant ice microcapsule material

2.1 Plant based anticoagulant
In this study, the core component of anticoagulant ice microcapsule material is plant-based anticoagulant ice agent, which is obtained from plant straw through a series of biochemical reactions. The constituent elements are mainly carbon, hydrogen and oxygen, without any chloride, sulfate and nitrite. The ice melting capacity and freezing point test are shown in Table 1 below, and the test ambient temperature is -20 ℃.

| Test items                  | Plant based anticoagulant | 20% sodium chloride snow melting agent | 40% potassium acetate snow melting agent |
|-----------------------------|----------------------------|----------------------------------------|----------------------------------------|
| Ice melting capacity (ice melting quality) | 9.2g                      | 3.6 g                                  | 4.5 g                                  |
| Freezing point              | -48℃                      | -16℃                                  | -29℃                                  |

2.2 Microcapsule structure
In this study, the anticoagulant ice microcapsule material is synthesized by microcapsule technology. It is a multi-core microcapsule structure. The wall material has good chemical stability, good mechanical properties and slow-release effect.

2.3 Anticoagulant ice microcapsule material
In this study, the properties of anticoagulant ice microcapsule material are milky white powdery solid particles, with a particle size of about 0.06mm, which is equivalent to the particle size of mineral powder, has good high temperature resistance and workable mixing strength, and can replace some mineral powder in the mixture. Fig. 1 shows the appearance of anticoagulant ice microcapsule material; Fig. 2 is the morphology of anticoagulant ice microcapsule material under scanning electron microscope (SEM). The main technical indexes of anticoagulant ice microcapsule materials are shown in Table 2.

![Fig. 1 Appearance of anticoagulant ice microcapsule material](image1)

![Fig. 2 Morphology of anticoagulant ice microcapsule material](image2)
Table 2 Main technical indexes of anticoagulant ice microcapsule materials

| Appearance       | Specific gravity (g/mL⁻¹) | PH value 40g/L H₂O(20℃) | Water content (%) | Salt content (%) | Melting point (℃) | Sieve pass rate (%) |
|------------------|---------------------------|--------------------------|-------------------|-----------------|-------------------|---------------------|
| Milky white powder | 1.4±0.5                  | 6~6.5                    | <0.3              | 0               | 413.5             | 100 98.5 96.4       |
| Grey powder     | 2.3±0.5                   | 8~8.5                    | <0.5              | >70             | 800               | >90 70-90           |

3. Study on properties of anticoagulant ice microcapsules

3.1 Test material
There are two kinds of materials used in this test, one is the self-developed anticoagulant ice microcapsule material, and the other is the salt storage material. The main components are sodium chloride, calcium carbonate, iron oxide, etc. The main technical indexes are shown in Table 2.

3.2 Water solubility test

![Fig. 3 Anticoagulant ice microcapsule material](image1)

![Fig. 4 Comparison materials](image2)

Before the test, weigh 3G anticoagulant ice materials respectively, add them into the water, stir them with a glass rod at a uniform speed for 2min, prepare the aqueous solution, and observe the state of the aqueous solution, as shown in Fig. 3 and Fig. 4.

It can be seen from Fig.3 and Fig.4 that compared with the aqueous solution of anticoagulant ice microcapsule material, the comparison material is hydrophobic, resulting in material agglomeration in the aqueous solution, and some materials float on the water surface. If applied to the micro surface treatment technology, the material will cause potential problems such as uneven dispersion and agglomeration in emulsified asphalt, The anticoagulant ice microcapsule material does not agglomerate in the aqueous solution, and is easy to disperse and mix evenly under stirring, which will not have a negative impact on the implementation effect.

3.3 Ice melting capacity test
In this study, the two sample aqueous solutions were tested under the same environment. The two sample aqueous solutions were placed at -5℃ for 4 hours and further extended to 12 hours to observe the freezing of the aqueous solution. The test results are shown in Fig. 5 and Fig.6.
As can be seen from Fig. 5 and Fig. 6, the samples were taken out after 4 hours for observation. When the small beaker was placed obliquely, it was observed that both solutions could flow without icing, indicating that both anticoagulant ice materials have certain snow melting and ice melting ability; In order to study the sustainability of the anticoagulant ice performance of the material, the project team continued to put the solution back to the environment of -5°C and observed the freezing of the aqueous solution after 12 hours. It was found that the aqueous solution of the anticoagulant ice microcapsule material could still flow without freezing, while the aqueous solution of the comparison material had frozen. It shows that the anticoagulant ice performance of anticoagulant ice microcapsule material is better than that of the comparison material under continuous freezing state.

3.4 Cyclic freezing test
Prepare the aqueous solutions of the two materials according to the above method, place them at -5°C for 4 hours, observe the first freezing condition, then gently pour out the solution in the middle and upper part of the beaker (retain the material sunk at the bottom), add water again, and continue to place them at -5°C for 4 hours, cycle the above steps to observe the freezing condition of each aqueous solution, so as to analyze the slow-release effect of the material, The test results are shown in Fig. 7.

| Frequency | First | Second | Third | Fourth | Fifth |
|-----------|-------|--------|-------|--------|-------|
| Anticoagulant ice microcapsule material | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) | ![Image](image5) |
| Comparison materials | ![Image](image6) | ![Image](image7) | ![Image](image8) | ![Image](image9) | ![Image](image10) |

Fig. 7 Circulating freezing test of aqueous solution of two materials

It can be seen from figure 7 above that the anticoagulant ice microcapsule material is frozen at the fifth cycle, while the comparison material is frozen at the third cycle, which shows that the anticoagulant ice microcapsule material has obvious slow-release effect. On the actual pavement, with the slow release of anti icing agent at the same interface and in the same state, it can inhibit ice condensation more times; When combined with the micro surfacing technology, with the wear of the micro surfacing surface, the new anticoagulant ice microcapsule material is in contact with the outside world, which can prolong the pavement and inhibit the freezing again.

4. Study on micro surface compounding technology of anticoagulant ice

4.1 Micro surfacing design
There are two types of mineral aggregate gradation for micro surfacing in China: MS-2 type and MS-3 type. In this paper, the mineral aggregate grading is the median value of MS-2 grading range, and the two aggregates of 0-3mm and 3-6mm are mixed according to the proportion of 60:40. The sand equivalent is 70. The aggregate: modified emulsified asphalt: added water: cement: anticoagulant ice material = 100:7:5.5:1.5:1.5.
4.2 Study on the effect of anticoagulant ice

4.2.1 Sponge ice melting test

Pour the mixture at the micro surface of anticoagulant ice on the surface of Marshall test piece without demoulding. After it is fully formed, put the sponge saturated with water on the surface of test piece, put it into the low-temperature control box, set -5℃ and constant temperature for 4h, use manpower to separate the sponge from the test piece, and record the difficulty of separating the sponge from the test piece surface. The test results are shown in Fig. 8 and Fig. 9.

It can be seen from Figure 8 and Figure 9 that the blank group did not add anticoagulant ice material, so it is difficult to separate the sponge after the test, indicating that the ice layer has been frozen with the mixture at the micro surface, while the self research group can easily separate the sponge, and the separated sponge is clean and free of mixture impurities, indicating that the anticoagulant ice microcapsule material has the effect of inhibiting ice condensation and obvious effect.

4.2.2 Ice adhesion test

In order to further verify the anti freezing effect of anti freezing ice micro surface mixture, this study designed the surface ice layer adhesion test of anti freezing ice micro surface mixture to verify the adhesion between anti freezing ice micro surface mixture and ice layer. It can be seen from table 3 that the adhesion of the ice layer of the mixture at the micro surface of anticoagulant ice is much less than that of the mixture at the ordinary micro surface, which means that even if the micro surface of anticoagulant ice cannot melt ice and snow in time, it can prevent the ice layer from closely bonding with the original road surface, so as to better deicing.

| Mixture type     | Ordinary micro surfacing | Anticoagulant ice micro surface |
|------------------|---------------------------|---------------------------------|
| Ice adhesion (N) | ≫35                       | 3.5                             |
| Average value    | ≫35 N                     | 4.1 N                           |

4.3 Study on road performance

4.3.1 Cohesion test

The test results of cohesion test are shown in Table 4 below:
### Table 4 Cohesion test results

| Curing time (min) | 30 | 60 |
|------------------|----|----|
| Test material    | Blank group | Anticoagulant ice Material Group | Blank group | Anticoagulant ice Material Group |
| Cohesion (N▪m)   | 1.4 | 1.3 | 1.8 | 1.6 |
| Technical requirement (N▪m) | ≥1.2 | | ≥2.0 |

It can be seen from table 4 that the cohesion of the two groups of samples is greater than 1.2N at 30min. Both meet the requirements, and the cohesion results at 60min are less than 2.0. This may be a problem in the grading design of slurry mixture, but it does not affect the comparative analysis. It can be seen from table 5 that the cohesion of anticoagulant ice material group is significantly less than that of blank group, which shows that anticoagulant ice microcapsule material has a certain impact on the cohesion of slurry mixture.

#### 4.3.2 Wet wheel wear test

The test results are shown in Table 5 below:

It can be seen from table 5 that the wet wheel wear of the two groups of samples meets the requirements in 1H and 6D. Compared with the blank group, the wet wheel wear value of the anticoagulant ice microcapsule material is relatively large, which shows that the anticoagulant ice microcapsule material has a certain impact on the wet wheel wear of the slurry mixture.

### Table 5 Wet wheel wear test results

| Time | 1h | 6d |
|------|----|----|
| Test material | Blank group | Anticoagulant ice Material Group | Blank group | Anticoagulant ice Material Group |
| Wear value (g▪m⁻²) | 73 | 102 | 151 | 189 |
| Technical requirement (N▪m) | ≤540 | | ≤800 |

#### 5. Conclusion

1. In this study, a non-chlorine environmental protection anticoagulant ice microcapsule material is proposed. It is a multi-core microcapsule structure composed of capsule core and capsule wall. The particle size is less than 0.075mm. It has good chemical stability, good mechanical properties and slow-release effect. When applied to pavement, it will not affect the quality of road engineering.

2. Through the test of anticoagulant ice effect, anticoagulant ice microcapsule material has significant anticoagulant ice effect, and is better than salt storage anticoagulant ice material.

3. Through the analysis of the road performance of the micro surface, the anticoagulant ice microcapsule material has a certain impact on the cohesion and wet wheel wear of the slurry mixture, but they all meet the specification requirements.

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