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Research on Effects of Deicing Salt on Adhesion properties between Asphalt Mortar and Aggregate

Abstract. *Through working out a indoor plan of the effects of deicing salt on adhesion properties between asphalt mortar and aggregate, based on innovative experiments with water boiled method to analysis of the effects of deicing salt on adhesion properties between asphalt and basalt and the effects of deicing salt on adhesion properties between SBS modified asphalt and basalt. The results show that specimens have a greater difference in adsorption capacity with the different effect solutions, through the effect of CaCl2、NC, the adhesion properties of asphalt and mortar and aggregate have been improved to some extent. In addition, through the effect of different deicing salt, the discrete levels of adsorption capacity of specimen different are different, through the effect of CaCl2, adhesion improving while the instability of adsorption capacity have appeared, but NC is relatively stable. Therefore, comprehensive consideration of the appropriate choice of the type of deicing salt can effectively reduce the effects of deicing salt on adhesion properties between asphalt mortar and aggregate.*

Streszczenie. *Artykuł analizuje wpływ soli użytej do odlodzenia na właściwości przyczepności między asfaltem a kruszywem. Odpowiedni dobór soli odmrażającej ma istotny wpływ na tę przyczepność. (**Badania wpływu soli odladzającej na przyczepność między warstwą asfaltu a podłożem**)*

Keywords: Deicing salt; Adhesion properties; Asphalt mortar; Powder-binder ratio; adsorption capacity; Adsorption particle size
Słowa kluczowe: odladzanie , sól, przyczepność, asphalt.

Introduction

Currently, the environmental pollution and structure corrosion caused by the use of deicing salt on the roads to social and economic causing more serious effects [1~2]. Domestic and foreign researchers on the development of deicing methods, the development and improvement of deicing salt, damage of deicing salt do a lot of research, but few studies have related to the effects of deicing salt on asphalt pavement performance. Therefore, to carry out the research of resistance of deicing salt corrosion of asphalt road has important practical significance. Among them, the reduction of adhesion properties between asphalt mortar and aggregate caused by deicing salt is one of the key issues.

The stripping of asphalt mixture is one of several common destruction phenomenons, it is the asphalt from the surface of adhesion aggregate to leave, and then fall off from the aggregate surface, and it is a destruction process of asphalt loss adhesion properties on aggregate [3]. The presence of water often leads to adhesion properties between asphalt mortar and aggregate become a serious problem, as water more easily than asphalt infiltrates aggregate surface, reduce adhesion properties between asphalt mortar and aggregate, even the loss of bond strength, resulting in water damage to asphalt mixture. The aggregate that as one of the most basic component materials of asphalt mixture be wrapped with asphalt as a whole, the adhesion properties for resistance of water damage of asphalt pavement also has important significance [4~8]. In this paper, through the improved adhesion properties test, research the adhesion properties of aggregate and asphalt and mortar after deicing salt by water boiling, to evaluate the effects of deicing salt on adhesion properties of aggregate and asphalt and mortar, to provide reference for a reasonable choice of type of deicing salt.

Deicing Salt and Its Action Principle

Definition and types of deicing salt

The salt of used to reduce the freezing point of ice is called deicing salt. Currently deicing salt can be divided into three categories：the first type is chloride salt, such as calcium chloride, magnesium chloride, sodium chloride, etc; the second type is non-chloride salt (organic or inorganic salts, amines, alcohols), such as calcium magnesium acetate (CMA), potassium acetate, etc; the third type is hybrid:1) chloride salt+ non-chloride salt. 2) chloride salt+ non-chloride salt+ corrosion inhibitor. 3) such as a deicing salt content of 43% calcium magnesium acetate and 57%sodium chloride.

Status of the use of deicing salt

So far, a major component of deicing salt is mainly sodium chloride. Sodium chloride is a material of a good performance of reduces the freezing point and ample supply, low-cost. From the technical information as access, difficult to find more suitable than sodium chloride deicing salt. Therefore, although sodium chloride has many shortcomings, but some countries of well-developed transport still use it, and mostly dry spray method.

Action principle of deicing salt

Main components of deicing salt are organic or inorganic soluble substances, after sowing by liquid or solid, form dilute solution, with continuity of dilute solution. According to the law of the Urals, the presence of solute can reduce the vapor pressure of solvent. When a small amount of solute B dissolved in solvent A to form a dilute solution, then the temperature of solid pure solvent A that precipitates from the solution, the freezing point of solution will be lower than it of pure solvent in the same external pressure. This is the phenomenon of freezing point depression. The saturated vapor pressure of Solid and liquid is not only a function of temperature, and a function of external pressure. But the change of external pressure on the vapor pressure has little effect.

Application of thermodynamic principles to derive the quantitative relationship of lower value of freezing point and composition of solution as follows:

(1) $$\Delta T_f = K_f m$$

where K_f- Molar freezing point Lower constant，water is 1. 86 K kg mol^{-1}, m - Quality molality, approximately equal molality, ΔT_f- the value of freezing point decline, unit ℃.

Test Plan

In the test process of study of effects of deicing salt on adhesion properties, comparing the specimens by water boiling and the specimens by deicing salt boiling can be found, it is not very different from the peel extent, however, the change in the appearance of the specimen is a clear difference, therefore hope that by an intuitive method can

quantitatively contrast analyzed the changes of adhesion properties of asphalt after effects of each solutions, to propose a new method of evaluation of adhesion properties. In water boiling methods due to the effects of liquid include two aspects: the peeling of asphalt membrane and the reduction of adhesion properties of asphalt. In view of the shortcomings of traditional adhesion properties test and the above reasons, proposed a new method of evaluation of adhesion properties, its main feature is the addition of evaluation index, on the one hand, the degree of asphalt membrane peeling, on the other hand, the changes of adhesion properties of asphalt and mortar [9].

Specific Test Methods and Procedures

1) Choose the coarse aggregate that particle size greater than 13.2mm, washing the coarse aggregate particles, drying heated in 105 ℃ oven;

2) The coarse aggregate be immersed in hot asphalt or mortar that has been heated to 130 ~ 150 ℃(appropriately increasing the temperature of modified asphalt), infiltrate 45s, makes the asphalt membrane fully wrapped cover on the aggregate surface.

3) Until the aggregate cooling to room temperature, be immersed in boiling water, makes water keep micro boiling state in beaker, Infuser 3min, remove the aggregate, hang up to dry[10];

4) Makes the dry aggregates into 35 ℃ constant temperature box keep 1h, weighing its quality (m0) after 1h, makes the specimens be rolled a circle in 0.3mm or 0.6mm fine aggregate basin by tweezers, then weighing its quality (m1) by the electronic balance that precision is 0.001g, difference value of quality of m0 and m1 is the adsorption capacity of aggregate on fine aggregate (m2), after equal quality conversion, the adhesion properties of aggregate after water boiling can be evaluated.

The improvement measures of new methods of adhesion properties

1) When select the coarse aggregate, must choose it of shape rules, to ensure the surface area is not poor too far in the cases of same volume.

2) Of the selected aggregate, take conversion when weigh the adsorption quality in the final. As the quality of a coarse aggregate is 5.5g, its capacity of adsorb fine aggregate is 0.1g, the other one is 7g, its capacity of adsorb fine aggregate is also 0.1g, thus they will be converted into 6g, after converted, the capacity of adsorb fine aggregate of a coarse aggregate that its quality is 5.5g is 6×0.1/5.5＝0.11g, while the one that its quality is 7g is 6×0.1/7＝0.086g.

The test plan has the following characteristics: The main consideration of effects of water, NaCl, CaCl2 and NC to the asphalt-aggregate system makes boiled solution be used NaCl, CaCl2, and NC instead of; In order to take full account of the effects of deicing salt on asphalt and asphalt mortar, produced a pure asphalt-coarse aggregate specimensand asphalt mortar-coarse aggregate specimens to test, the powder-binder ratio of asphalt mortar is 0.6、0.8、1.0、1.2、1.4.

Adhesion Properties Test With Method of Water Boiling

The test results of effects of deicing salt on the adhesion properties of asphalt and mortar and aggregate.

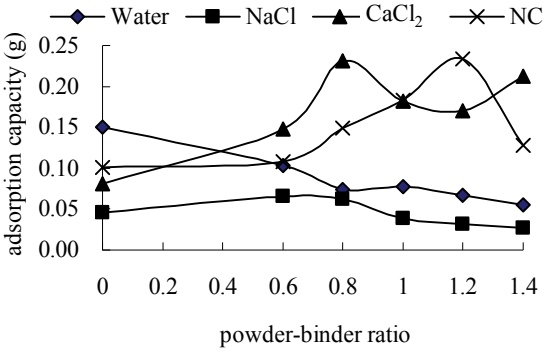
The test results of adhesion properties between asphalt mortar and aggregate in table 1, Contrast relationship of adhesion properties after effects of deicing salt shown in Figure 1~Figure 7.

Table 1 the test results of adhesion properties after effects of different deicing salt

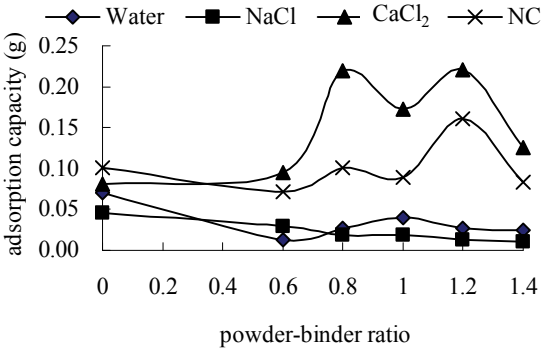
Type of asphalt	Type of deicing salt	Particle size of adsorption	Powder-binder ratio					
			0	0.6	0.8	1	1.2	1.4
Asphalt	water	0.3mm	0.1497	0.1037	0.0735	0.0772	0.0668	0.0546
	NaCl		0.0463	0.0660	0.0617	0.0393	0.0316	0.0274
	CaCl2		0.0811	0.1478	0.2314	0.1813	0.1703	0.2121
	NC		0.1013	0.1080	0.1495	0.1835	0.2336	0.1278
	water	0.6mm	0.0700	0.0124	0.0266	0.0395	0.0274	0.0247
	NaCl		0.0463	0.0289	0.0189	0.0191	0.0130	0.0109
	CaCl2		0.0811	0.0946	0.2191	0.1721	0.2204	0.1251
	NC		0.1013	0.0716	0.1007	0.0887	0.1608	0.0838
SBS modified asphalt	water	0.3mm	0.0900	0.0292	0.0371	0.0273	0.0338	0.0437
	NaCl		0.0608	0.0108	0.0085	0.0118	0.0107	0.0159
	CaCl2		0.1917	0.3208	0.2615	0.2700	0.3133	0.2831
	NC		0.2036	0.1658	0.1866	0.1808	0.1817	0.1893
	water	0.6mm	0.1630	0.0069	0.0168	0.0102	0.0131	0.0181
	NaCl		0.0588	0.0181	0.0067	0.0091	0.0017	0.0053
	CaCl2		0.1467	0.2489	0.2050	0.2340	0.3075	0.2262
	NC		0.0979	0.1558	0.1754	0.1557	0.1312	0.1250

From Table 1 and Figure 1 to Figure 5 can be seen:

1) With the powder-binder ratio increases, by the effect of each solution, regularity of changes of adsorption capacity of the specimen is not strong. For asphalt and mortar-coarse aggregate system, only by the effect of NaCl, the adsorption capacity that adsorb fine aggregate of 0.3mm and 0.6mm with the powder-binder ratio decreases is increases, but the degree of change is small; For SBS modified asphalt and mortar-coarse aggregate system, by the effect of each solution, the adsorption capacity of specimens of pure asphalt-coarse aggregate are larger, with the powder-binder ratio increases, regularity of changes of adsorption capacity of each specimen is also not obvious.

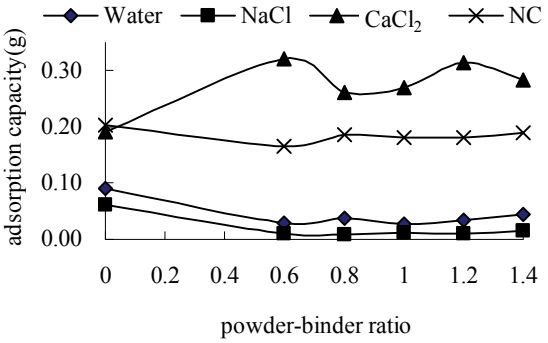


a) The absorption of fine aggregate of 0.3mm after effects of each solution

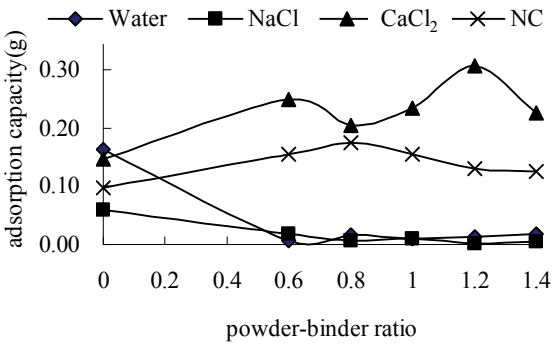


b) The absorption of fine aggregate of 0.3mm after effects of each solution

Figure 1 the changes relationship that adsorption capacity of asphalt and mortar-coarse aggregate system with powder-binder ratio

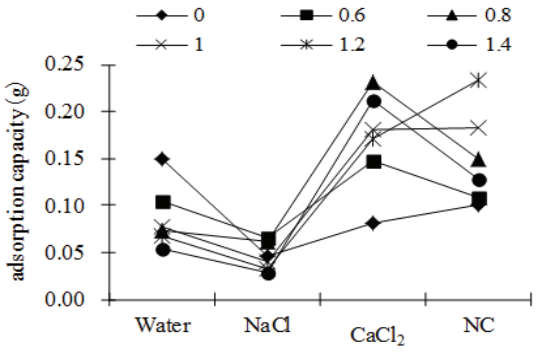


a) The absorption of fine aggregate of 0.3mm after effects of each solution

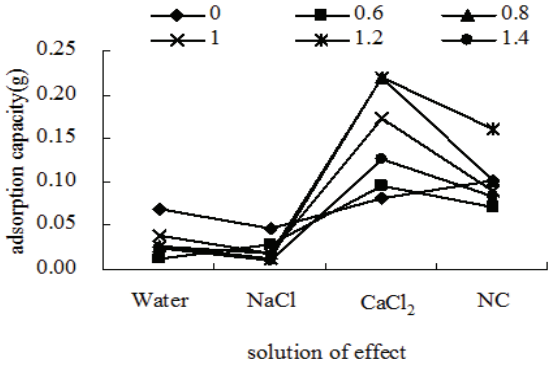


b) The absorption of fine aggregate of 0.3mm after effects of each solution

Figure 2 the changes relationship that adsorption capacity of SBS modified asphalt and mortar-coarse aggregate system with powder-binder ratio

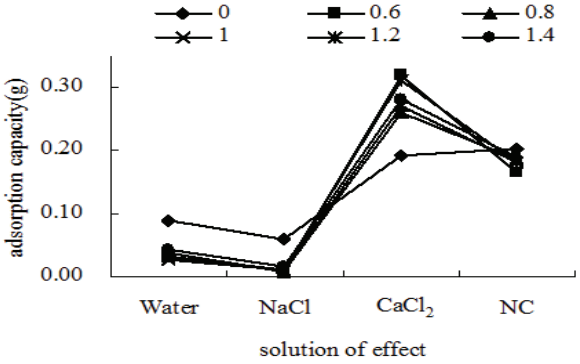


a) The absorption of fine aggregate of 0.3mm after effects of each solution

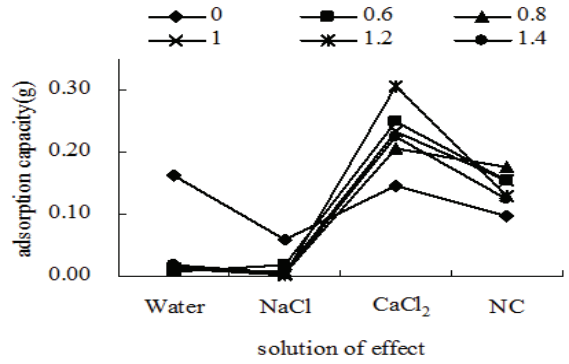


b) The absorption of fine aggregate of 0.3mm after effects of each solution

Figure 3 the changes relationship that adsorption properties of asphalt and mortar-coarse aggregate system with solution of effect

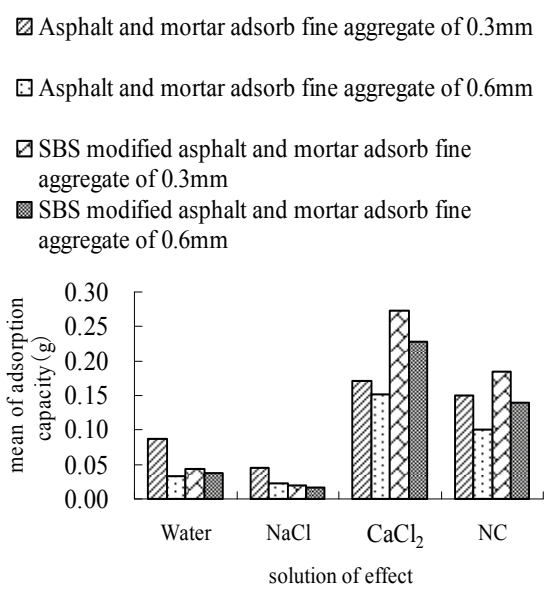


a) The absorption of fine aggregate of 0.3mm after effects of each solution

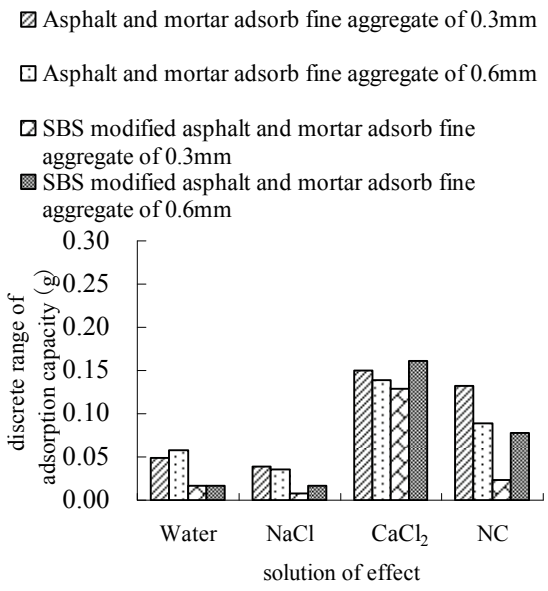


b) The absorption of fine aggregate of 0.3mm after effects of each solution

Figure 4 the changes relationship that adsorption properties of SBS modified asphalt and mortar-coarse aggregate system with solution of effect



a) The changes of adsorption capacity with solution of effect



b) The changes of discrete range of adsorption capacity with solution of effect

Figure 5 the changes relationship that mean and discrete range of adsorption capacity of asphalt and mortar with solution of effect

2) With different solution of effect, the adsorption capacity of specimen is quite different. As measured by the effects of water, by the effect of NaCl, the mean of adsorption capacity of each system reduced, corresponding to asphalt-0.3 (For convenience, the system that specimens of asphalt and mortar-coarse aggregate adsorb fine aggregate of 0.3m be abbreviated as asphalt-0.3 in here, the same below) 、asphalt -0.6、SBS-0.3、SBS-0.6，the degree of reduction respectively are 48.18%、31.65%、54.62%、56.29%；By the effect of CaCl2, the mean of adsorption capacity of each system greatly increased, corresponding to asphalt-0.3 、asphalt -0.6、SBS-0.3、SBS-0.6，the degree of increase respectively are 48.18%、31.65%、54.62%、56.29%；By the effect of NC, the mean of adsorption capacity of each system also greatly increased, the degree of increase corresponding to each system respectively are 71.96%、202.55%、324.28%、268.70%.

The reason of this phenomenon is which the most active component in asphalt (naphthenic and asphaltousacid) belong to a polymer carboxylic acid , its polar end is a carboxyl (COOH), and passive part is hydrocarbon-based (R), hydrogen and other cations (Ca2+) exchange in carboxyl, form the naphthenic acid salt that insoluble in water, but it can dissolve in non-polar polymer hydrocarbons and oil, when the asphalt in solution of containing calcium ions be heated, because Ca2+ produced absorption to the largest active components of asphalt, thus increasing the water stability of asphalt and aggregate; On the other hand, the chemical adsorption of asphalt and surface of mineral aggregate, the same it can be produced in mineral aggregate that containing monovalent metal salts(sodium, potassium, etc.) But this time it form a water-soluble naphthenic sodium or potassium salts—a typical soap, They act as the role of emulsifiers under action of water, resulting asphalt emulsion, and then asphalt membrane was stripped by water. Therefore, NaCl on adhesion properties would have a negative effect, and then CaCl2 can produce the chemical adsorption effect.

3) With different solution of effect, the degrees of discrete of adsorption capacity of specimens are different. Such as in system of asphalt-0.3,by the effect of water, the change ranges of adsorption capacity is 0.0546g ~ 0.1497g, the degree of discrete is 0.0951g, while by the effect of NaCl、CaCl2、NC, the degrees of discrete respectively are 0.0386g、0.1503g、0.1323g，and by the effect of CaCl2, the degree of discrete of adsorption capacity is maximum, explain by the effect of CaCl2, specimen due to the different powder-binder ratio result instability of adsorption capacity, the sensitivity that CaCl2 on change of powder-binder ratio is larger. Through a comprehensive comparison found，As measured by the effects of water. By the effect of NaCl, the degrees of discrete of adsorption capacity of specimen of each system reduced, corresponding to asphalt-0.3 、asphalt -0.6、SBS-0.3、SBS-0.6，the degrees of discrete of adsorption capacity respectively reduced 21.38%、38.54%、54.88%、2.44%；By the effect of CaCl2, the degrees of discrete of adsorption capacity corresponding to specimen of each system increased, its degrees respectively are 206.11%、141.84%、687.20%、857.14%；By the effect of NC, the degrees of discrete of adsorption capacity also increased, its degrees respectively are 169.45%、54.86%、39.02%、361.31%. Explain by the effect of CaCl2, adsorption capacity with the changes of powder-binder ratio is the most unstable, NC followed by, the effect of NaCl is minimal.

Conclusions

Through the test of adhesion properties by water boiling method of deicing salt analysis of the influence law of deicing salt on adhesion properties of asphalt and SBS modified asphalt and mortar and aggregate, the results show:

1) With powder-binder ratio increase, by the effect of NaCl, the adsorption capacity of Specimen on fine aggregate gradually reduced; By the effect of CaCl2、NC, the changes of adsorption capacity without obvious rule.

2) By the effects of different deicing salt, the adsorption capacity of Specimen is different. As measured by the effects of water, by the effect of NaCl, the adsorption capacity reduced; By the effect of CaCl2, the adsorption capacity greatly increased; By the effect of NC, the adsorption capacity increased, but the range of increase less than the effect of CaCl2, it explain that the effects of

CaCl2、NC improving the adhesion properties of asphalt and mortar and aggregate in a certain degree.

3) By the effects of different deicing salt, the degrees of discrete of specimen are different. As measured by the effects of water, by the effect of NaCl, the degrees of discrete little; By the effect of CaCl2, the degrees of discrete great; By the effect of NC, the degrees of discrete too great, but less than the effect of CaCl2, it explain that the effect of CaCl2 appear the instability when it improve the adhesion properties, and NC relatively stable.

In conclusion, the effects of deicing salt on adhesion properties of asphalt and mortar and aggregate closely related the type of deicing salt and powder-binder ratio, the choice of appropriate type of deicing salt can effectively reduce the effects of deicing salt on adhesion properties of asphalt and mortar and aggregate.

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