AMELIORATION AND EXAMINATION OF LASTING EFFECTS OF PULVERULENT CHLORIDE COMPOUND-BASED FREEZE INHIBITING PAVEMENTS

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1. Introduction

The pulverulent chloride compound, a deicing material which is in principle expected to realize its deicing effect by lower freezing point due to the leakage of its content from the pavement, was introduced to Japan from German in 1980's. It is used in an asphalt mixture as filler in 7-8% of the weight of the mixture. Therefore, the pulverulent chloride is suitable for the F-type asphalt mixture for its relatively high filler content that is preferable for cold area with snow accumulation in Japan.

It was in 1990 that spike tires were prohibited in Japan mainly due to the occurrence of serious wearing deterioration of pavement surface. New deicing materials thus were introduced for deicing purpose, but have difficult in prolonging the duration of deicing effect. In this study, effort is made for mix design of asphalt mixtures so that the pavement using the pulverulent chloride compound can extend its duration of the deicing property. A mix design method, which is expected to have a good duration of deicing property with no pavement wearing deterioration, is proposed and test for the validation of its effectiveness of long last deicing is devised. The applicability of the method proposed is verified. In addition, the pulverulent chloride compound is improved. The compound, which is expected to effective for recycled asphalt mixtures and mixtures used in ordinary area, is trial manufactured.

2. Deicing material

An outline of the deicing material used in the study is presented in Table-1.

Table –1 Property of the deicing materials

Appearance	Properties		
Properties	Specific gravity	2.25-2.35	
	Unit Mass	0.93-0.99	
	Grade	Size	(%)
		150 mm	>90%
		75 mm	75-90
	PH		8.0-8.5
	Water content (%)	<0.5	
	Salt content (%)	45-65	
Compositions	Sodium chloride, Calcium carbonate, Iron oxide II	Silicon, Magnesium,	Dioxide Oxide

3. Examination on the lasting ability of deicing property

3.1 Field investigation

The field investigation is carried out for confirming where the deicing effect disappeared in a long duration (6-9 years) and a short duration (1-2 years). The field investigation is summarized as follows:

(1) Results of investigation from pavements having a long duration of deicing effect

The presence of salt was confirmed by white crystal, the reaction compound with A_gN0_3 solution, on the pavement surface, and the concentration of salt leaked out was measured by Quantab chemical powder in all the pavements having a long duration of deicing effect. Besides, core samples from the pavements were tested on void ratio. It is showed that the void ratio of the mixtures changes from 4 to 6%.

(2) Results of investigation from pavements having a short duration of deicing effect

The mixtures for pavements having a short duration of deicing effect can be divided into two kinds:

(a) In pavements where traffic volume is light as classified 'L' in Japanese design code, there appeared a very big effect of deicing in the first year but the effect decreased significantly from the next year.

(b) In pavements where traffic volume is heavy as classified 'B' in Japanese design code, the deicing property lasted only a few months.

There is neither white crystal to be confirmed by A_gN0_3 solution nor detective salt by Quantab chemical powder on the pavements having a short duration of deicing effect.

It was further found by core samples that the void ratio of the mixture is as much as 10% in case of (a), but as less as 2% in case of (b). It is though in case (a) the high void ratio was caused by a light compaction of 94% applied to the mixtures in spite of the designed void ratio for the mix is only 4%. In case (b), the small void ratio possibly was though to be resulted from a heavy traffic especially under the wheels of the vehicle. It was did appeared the white crystal by A_gN0_3 solution and salt left in the mixtures was confirmed by burning method for the samples taken from away the wheels.

(3) Conclusions from the field investigation

- The mixture showed a 8-9 years duration of deicing property has a void ratio4-6%.
- In case that the mixtures show a big deicing effect in the first year after construction but

losing its effect in the early stage, it is because the mixtures are not sufficiently compacted leading a void ratio as much as 10%.

- In case that the effect of deicing property disappeared in spit of the presence of salt in the mixtures, this is because the void ratio is too small due to the application of the heavy traffic.

It is concluded that the crucial factor to influence the long last deicing property is the void ratio of the mixture.

3.2 A mix design method for a long lasting deicing property

It is naturally to accept the idea that an appropriate value of the void ratio may assure a long lasting deicing property of the mixtures due to the influence of the void ratio on the property, which was discussed in above.

Here in the study, the mix design method is discussed with an aim at improving the holding ability of the void ratio of the mixtures. Totally, 4 types of asphalt mixtures, namely dense-graded asphalt mixture (13F), dense gap-graded asphalt mixture (13F), fine-graded asphalt mixture (13F), and fine gap-graded asphalt mixture are examined because theses mixtures have experienced many the pulverulent chloride compound in Japan. The kind of mixture attached the letter F, which means a large fraction of filler in the mixture, is often used in cold area with snow accumulation in Japan.

(1) Investigation on the holding ability of void ratio

The holding ability of void ratio is evaluated considering the decrease of void ratio caused by traffic load in the future. The evaluation is accomplished by measuring the variation of void ratio with the rotary number of the gyratory compactor for the four types of the mixtures under the optimum asphalt content (OAC) obtained by the methods as indicated in Table –2.

Table –2 Methods to determine OAC

No.	Number of blow in Marshall test	Method to determine OAC	Symbolized as
1	50 for both sides	Pavement code *1	50 OAC
2	50 for both sides	Void ratio 4%	50-4% OAC
3	75 for both sides	Pavement code *2	75 OAC
4	75 for both sides	Void ratio 4%	75-4% OAC

Note: *1, It is an ordinary method adopted to determine OAC in Japan, see Asphalt Pavement Design Code (Japanese Road Construction Association, JRCA method)

*2, It is not specified for ordinary F type mixtures to blow 75 times, here the OAC is determined according to JRCA.

The void ratio left after 300 rotaries of all the four mixtures is calculated, as shown in Fig. 1, based on that the void ratio left after 50 rotaries is assumed as a unit. The void ratio left is defined as follow:

$$\text{Void ratio left (\%)}=\text{void ratio after 300 rotaries}/(\text{void ratio after 50 rotaries})\times 100\%$$

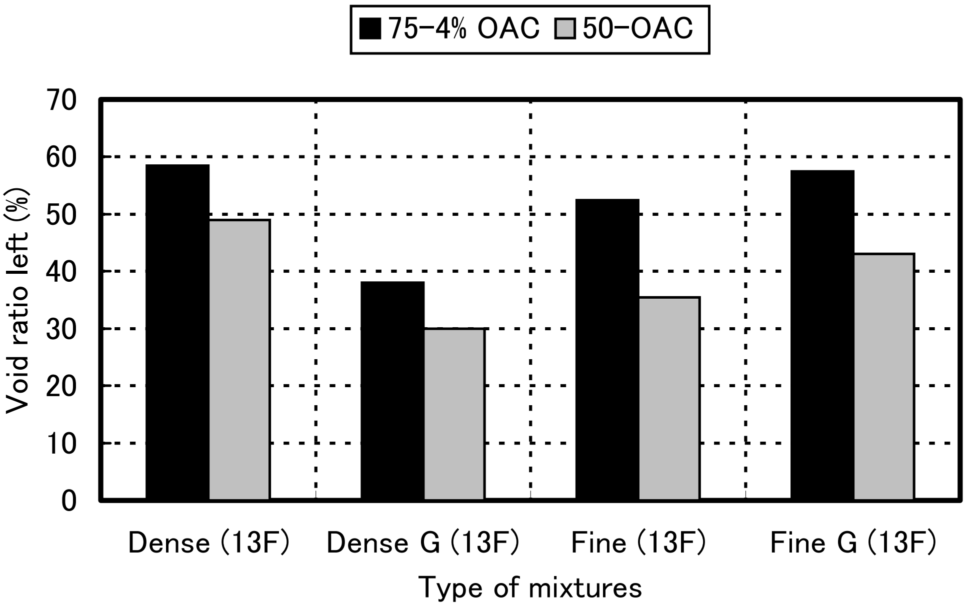

Fig.1 The void ratio left after Gyratory compaction

It can be observed that the void ratio left of the mixture with 75-4% OAC is 108-116% as much as that of the mixture with 50-OAC for all the four mixtures. That means the mixtures with the 75-4% OAC have a better holding ability of void ratio. It is further found by analysis of the tested results that the 4% OAC is located the in low limit side of the common asphalt content scope which is obtained by JRCA method. It is coincide, see Fig. 2, that the OAC obtained from JRCA is approximately the same as the average value of the low limit of the common scope of the asphalt content.

Therefore, it is possible for the mixture, which is prepared with 75 blows at the two sides of the sample in a low limit OAC, to achieve a long duration of deicing property.

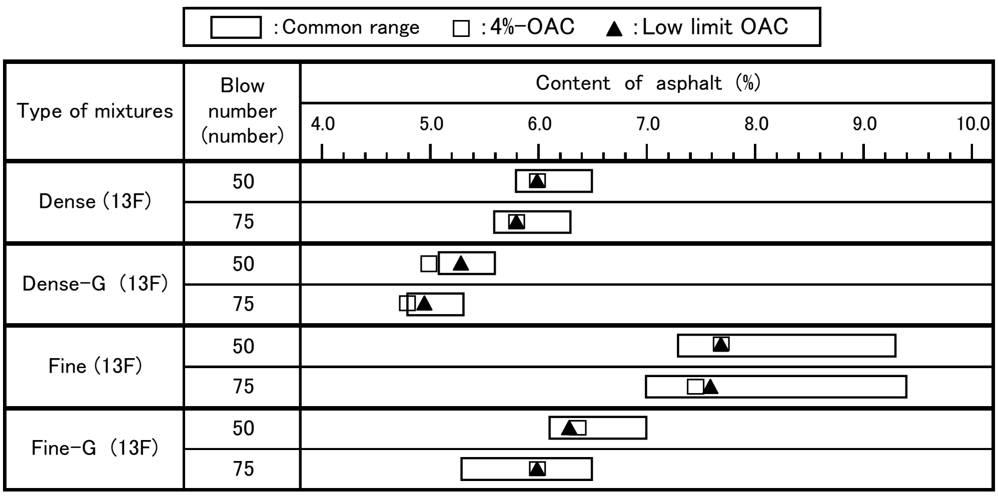

Fig.2 Result from mix design

3.3 Confirmation of the long duration of deicing property

(1) The confirmation method

It is proposed in the study that the confirmation of the long duration of deicing property is carried out by a test to measure the concentration of the salt density leaked out. The procedure is described as follows:

(a) To manufacture first a sample that is the same as what is usually used for wheel tracker test, then core boring is conducted for a test sample.
(b) To set up the test sample in a plastic cup as illustrated in Fig. 3.
(c) To pour 100 ml stilled water in the plastic cup and let the sample surface be merged under the water for 8 hours.
(d) To take some of the water containing with the leaked water and test the concentration of the salt density.
(e) To abolish the water left in the cup and then put it laterally for 16 hours, to make sure the sample to be dried before next step.
(f) To repeat from (a) to (e) as one cycle.

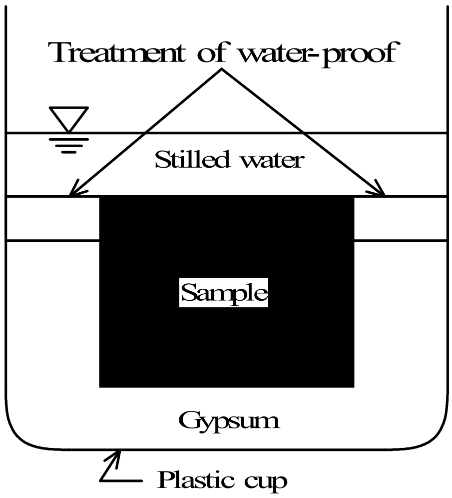

Fig.3 Test set for confirmation of the salt leaked out

(2) The relationship between the void ratio and the time lasted for salt to be measured

The relationship between the void ratio and the time lasted for salt to be measured is shown in Fig. 4. The accumulated salt leaked out in Fig.4 is defined as the total salt density leaked out in 100 ml stilled water.

It is indicated in Fig. 4 that the salt was still detectable even after 300 cycles (could be explained as the pavement surface merged under water 8 hours a day for 300 days) for those samples with a void ratio from 4.3 to 10%. Besides, the bigger the void ratio, the more the salt leaked out in every cycle. Consequently, the sample with a bigger void ratio disappeared the leakage of salt with a quicker speed than that with a smaller void ratio. The total salt leaked out from the samples is approximately the same what was added in it. It can be concluded from the result that the mix design method stressed the void ratio is an effective way to improve the long lasting property of deicing.

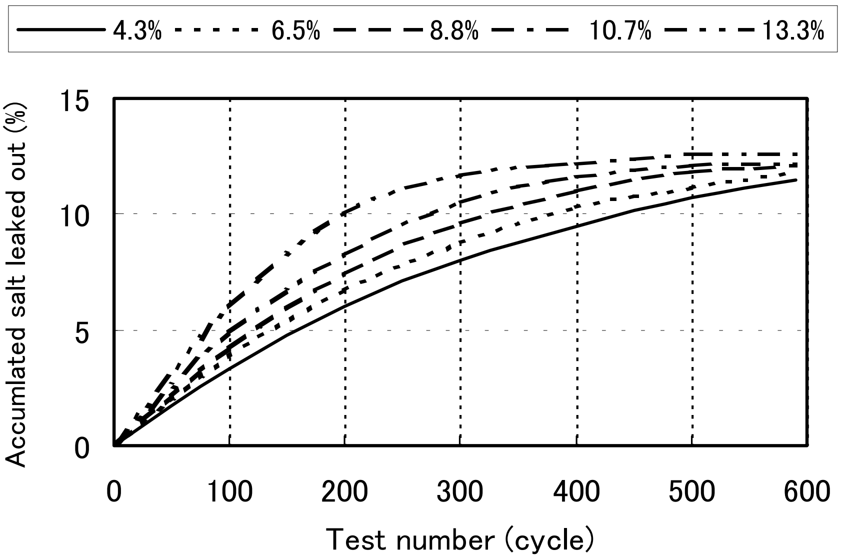

Fig. 4 The relationship between the accumulation of salt and the number of cycle

4. Investigation of an enlarged application for the deicing material

4.1 Change the grade

In recent year, the ordinary dense graded asphalt mixture (13) is being considered to be appropriate for the cold area to tackle the rutting problem occurred also in that area. In addition, the deicing pavement is required gradually in places not very cold area. The fraction of filler, which is replaced by the deicing powder contained, in ordinary mixture (13) is not as sufficient as the F type mixture, leading a lack of needed deicing materials and thus quick loss of the desired deicing property. It is therefore necessary to change the grade of the pulverulent chloride compound so that the dense graded mixture (13) is suitable for the deicing material. Here presented are the mechanical and deicing properties of the dense graded mixture (13) in which the pulverulent chloride compound with modified grade is used.

Fig.5 is a comparison between grades of the dense graded mixture (13F) used popularly in cold area and the dense graded mixture (13). The mixture (13) has less fraction passing sieve 2.36 mm and 0.075 mm, indicating a coarse grade mixture.

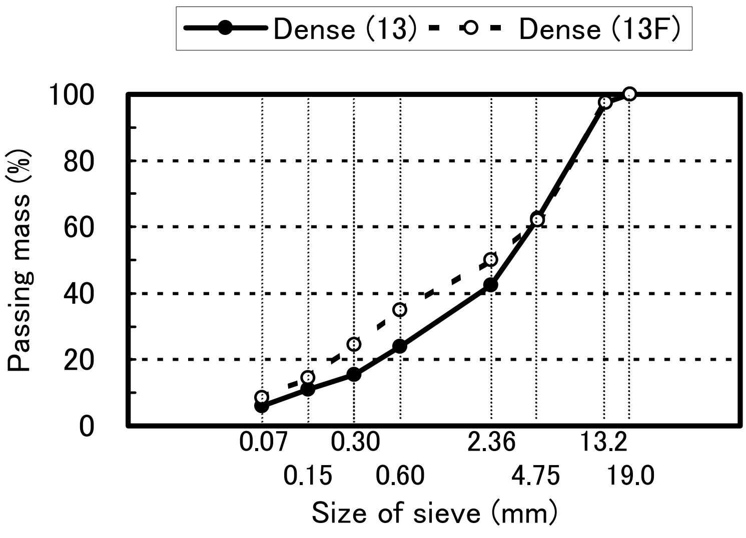

Fig.5 Grades of the dense graded mixture (13F) and the dense graded mixture (13)

4.2 Investigation of deicing material suitable for the dense graded mixture (13)

(1) Grade

The grade distributions, mainly with different masses passing the 0.075 mm sieve, of three trial products of deicing materials are listed in Table –3.

Table –3 Grade distributions of three trial products

Sieve size	600	300	150	75	Density
The traditional	100	96.0	90.0	75.0	2.32
Trial A	100	93.5	87.0	73.5	2.34
Trial B	100	91.0	82.5	68.0	2.39
Trial C	100	90.5	80.0	64.0	2.40

(2) Content added

Grade designs were performed by changing the content of the three trail products. The dense graded mixture can be met, see Table-4, by modifying the content of the three products. The grade using trial product C satisfied that of the mixture (13) when 7.1% of the deicing material is added. The amount of the deicing material is about that of the traditional deicing material needed for F-type mixture (13F).

Table-4 Grade design of aggregate for different deicing materials

	6#	7#	Coarse sand	Fine sand	Deicing material
Trial A	38.0	21.4	25.0	9.5	6.1
Trial B	38.0	21.3	25.1	9.0	6.6
Trial C	38.0	21.3	25.1	8.5	7.1

(3) Confirmation of deicing effect

The confirmation was evaluated by the ice strength under -3 degree on the samples with the grades shown in Table -4 (asphalt content: 5.5%). The results are presented in Fig.6. The result from the dense graded mixture (13F) with 7% of deicing material, showed in the same Fig. as control sample, is about that of trail product C.

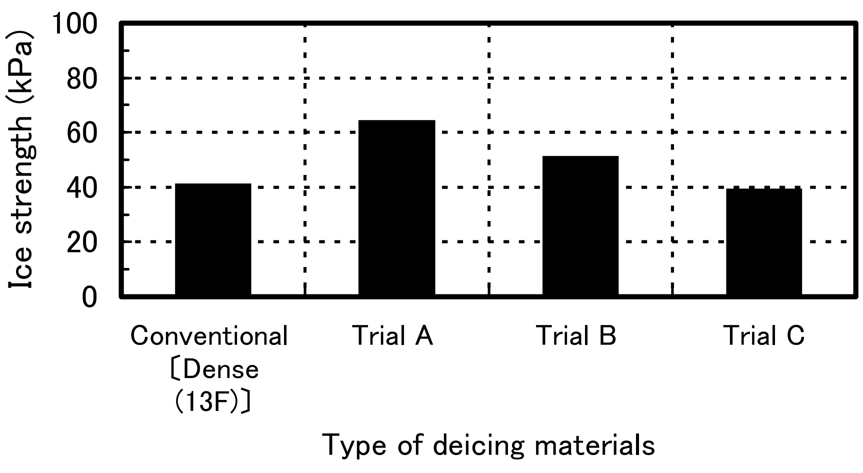

Fig. 6 The effect of deicing for different trial products

4.3 Evaluation of the trial product C

The trial product C was selected by matching the dense graded mixture (13F) and thought to be suitable for the dense graded mixture (13) in a best way of all the three with respect to the deicing effect. In the section, the mechanical properties including Marshall stability, wheel tracker test, and deicing effects including ice strength test under -3 and -5 degree as well as the measurement of the salt content were confirmed further.

(1) Mechanical properties

(a) Durability

Presented in Fig.7 is the result from immersion Marshall stability test together the dense graded mixture (13F) added the traditional deicing material. The stability left of the trial product C, 75%, is about the same as the dense graded mixture (13F).

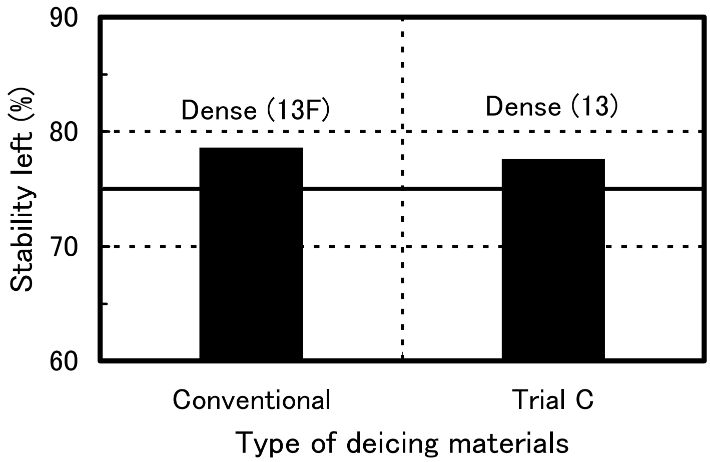

Fig.7 Result of immersion Marshall Test

(b)Flow resistance

The result from wheel tracker test is shown in Table -5. The dynamic stability (DS) of the trail product C added with amount of (7%) is almost the same that without any deicing material.

Table -5 The results from wheel tracker test

Types	**Mixture**	**DS (number/mm)**
Without deicing material	Dense graded mixture (13)	1050
Trail product C (7%)	Dense graded mixture (13)	970

(2)Deicing effect

(a) Ice strength

The test result of ice strength is presented in Fig. 8. The ice strengths of the dense graded mixture (13) added with trail product C are almost the same those of the F type dense graded mixture (13F) added with the traditional deicing material.

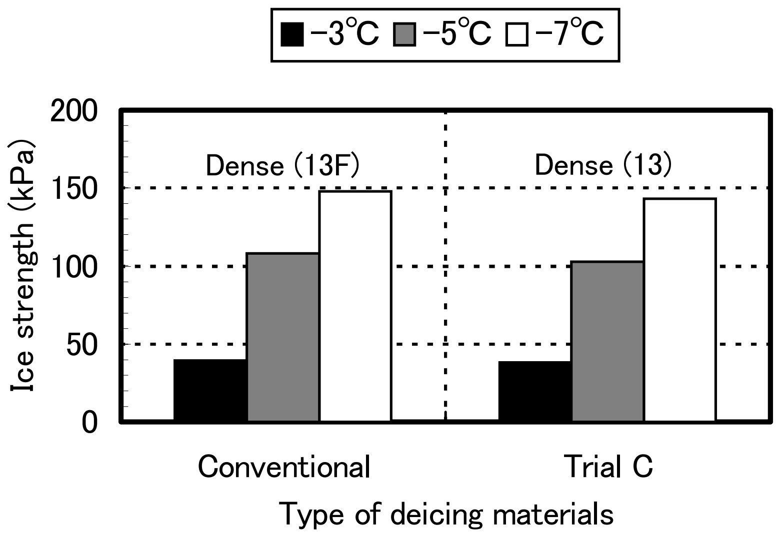

Fig. 8 The result of ice strength test

(b) Effect of long lasting deicing property

The result of the confirmation of the leakage of salt is shown in Fig. 9. The accumulation of salt leaked out from the dense graded mixture (13) is almost the same as that from the F type dense graded mixture (13 F). It is concluded from the results that the trial product C can be used for the dense graded mixture (13) with regards to the mechanical properties and long lasting deicing effect. The deicing ability of the mixture (13) is almost as good as that of the mixture (13F). In other words, the trial product C is applicable for the dense graded mixture (13F) used in ordinary areas.

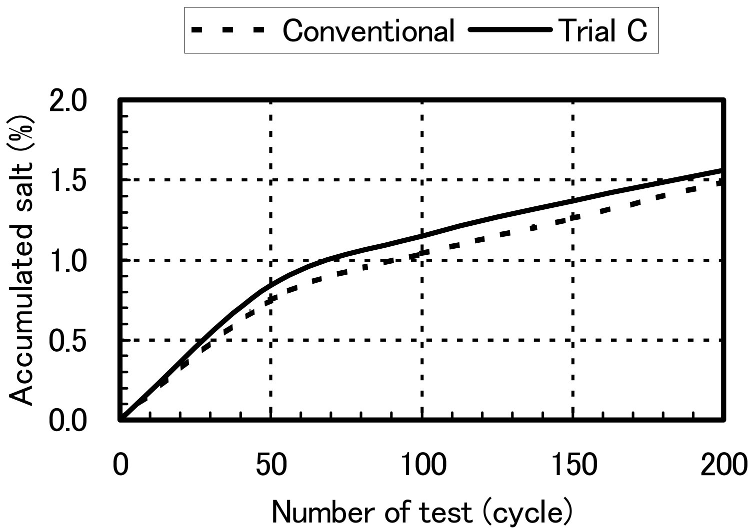

Fig.9 The result of the confirmation of the leakage of salt

5. Conclusions

The conclusions drawn from the study are summarized as follows:

(a) It is possible to get a required long lasting deicing property when optimum asphalt content is obtained under the condition that a compaction of 75 blows at two sides and a void ratio of 4 are adopted for sample preparation.

(b) A modified deicing material with coarse grade has been developed for recycled mixtures ordinary dense graded mixtures (13F).

6. Main references

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2) S. Suzuki, T. Kano and T. Maruyama, (1998), Study on lasing deicing properties in deicing asphalt pavements, Journal of Pavement Engineering, JSEC, Vol.4, pp. 249-256.