High-strength Cold Laid Asphalt Mixture Applicable for Heavy Traffic Roads and Roads in Snowy and Cold Regions

H. Inamoto & M. Nakatsuka & M. Jomoto
Institute of Research and Development, Taisei Rotec Corporation, Kounosu, Saitama, Japan

A. Kuno
TR Consultant Co., Ltd, Japan

ABSTRACT: In Japan, cold laid asphalt mixture that is used to fill pot holes has conventionally employed cut-back asphalt as a binder to ensure its workability at normal temperature. For this reason, the strength and water-resistance of cold laid asphalt mixture is lower as compared to hot asphalt mixture. To overcome this weakness, the cold laid asphalt mixture introduced herein uses additives consisting of the principal agent and a hardener that produce chain polymers by chemical reactions after application, and has the following characteristics: (1) storage and application at normal temperature are possible as with existing types of cold laid asphalt mixture, (2) 2 – 3 kN of Marshall stability at 60°C, which cannot be measured in the case of ordinary cold laid asphalt mixture, can be obtained, and (3) good water-resistance as the presence of water promotes development of the strength. We herein introduce the principles about how the cold laid asphalt mixture concerned develops the strength, properties of the mixture, as well as examples of applications to heavy traffic roads and to the repairs of pot holes on snowy and cold regions in the snow-melting season.

KEY WORDS: Cold laid asphalt mixture, asphalt repair material, pot hole, heavy traffic roads, Snowy and Cold Regions .

1 INTRODUCTION

Wheel path on heavy traffic roads and in intersections are prone to produce cracks and ruts, and on roads in wet conditions during winter season, pot holes (Photograph 1), can easily develop due to wearing and damage by snow chains. Especially, pot holes need to be dealt with promptly once they are made since they will quickly enlarge. However, asphalt plants that are in operation during winter season are limited in snowy and cold regions, and therefore cold laid asphalt mixture (hereinafter referred to as “cold mixture”) is used as emergent measures when hot asphalt mixture (hereinafter referred to as “hot mixture”) is not available.

In Japan, many types of existing cold mixtures that are used for the filling of pot holes employ cut-back asphalt as a binder to ensure workability at normal temperature. For this reason, the stability and water-resistance of cold mixture are lower than those of hot mixture, and such asphalt may deform or scatter early depending on the loading conditions and weather conditions.

In this paper, we introduce properties of the high-strength cold asphalt mixture (hereinafter referred to as the “cold mixture concerned”) in which improvements are made to overcome this weakness resulting in the stability and water-resistance comparable to those of the hot mixture. We also present examples of its applications to heavy traffic roads and snowy and cold regions in winter season.

Photograph1: A pot hole

2 HIGH-STRENGTH COLD LAID ASPHALT MIXTURE

Existing cold mixtures use cut-back asphalt as a binder to ensure its storage stability and workability, and development of the stability is largely dependent on the increased viscosity of the binder caused by the evaporation of the cut-back material. However, since cut-back asphalt is highly sensitive to temperature and its stability decreases when the temperature increases, it is less stable than the hot mixture (especially high-temperature (60°C) stability). Compared to this, the cold mixture concerned, in addition to using cut-back asphalt as with existing cold mixtures, employs 2 types of additives that produce chain polymers by chemical reactions after construction, increasing its stability (especially high-temperature (60°C) stability). Furthermore, ingenuity is exercised so that the additives will not react during the storage and the reaction itself is promoted by the catalytic role of the water content. The cold mixture characteristics are shown Table 1

Table1: Comparison of Cold Mixtures

	other Cold Mixtures	Cold Mixtures
Store at normal temperature	○	○
Constract at normal temperature	○	○
Mashall stability	cannot	2−3kN
Water resistance	×	○
Store for about a month	○	○
Less efflux of oil content in water	More	Less

3 PRINCIPLES OF STRENGTH DEVELOPMENT

In the cold mixture concerned, the flowing principles are applied for early development of the target stability:

(1) As shown in the conceptual diagrams of Figure1, additives consisting of the principal agent and the hardener that produce chain polymers after the chemical reaction are used to

develop the stability early after the application.

(2) Of the additives, by making the hardener capsule-like, the principal agent and the hardener are separated during storage and construction off to maintain the predefined constancy, enabling storage and construction at normal temperature.

(3) Capsules of the hardener are broken by the compaction energy during the construction, and the two additives contact each other to start the reaction, resulting in the development of stability after the construction.

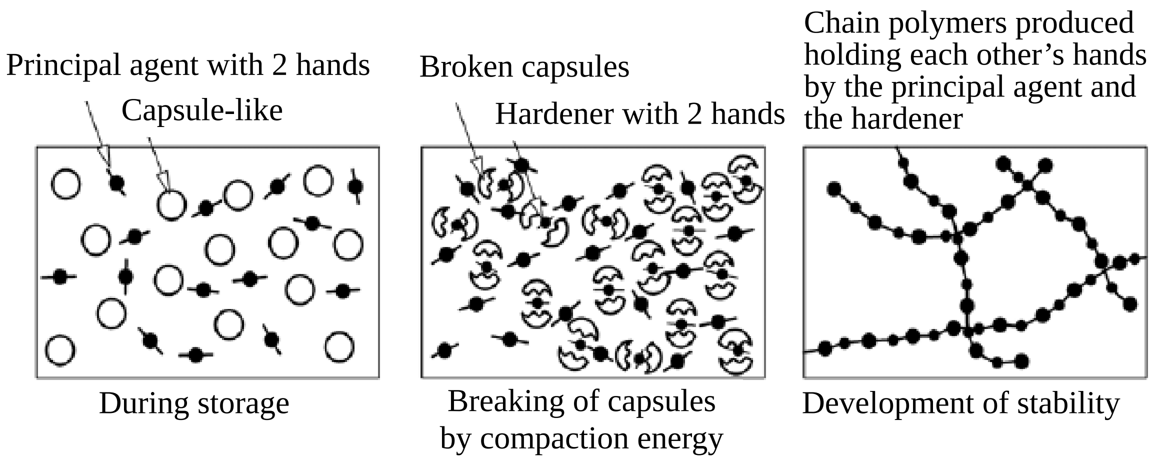

Figure1: Conceptual Diagrams of Strength Development

4 PROPERTIES OF HIGH-STRENGTH COLD ASPHALT MIXTURE

The properties of the cold mixture concerned are shown below. The cold mixture concerned was designed with an aggregate grading between fine-graded asphalt mixture (13) and dense-graded asphalt mixture (13), and with an optimal binder amount of 6.0%.

4.1 Marshall Stability

Case 1: The specimen was prepared by blowing 50 times on each side at 20°C, and after air-dry curing at 20°C for 3 days, tested at 60°C by 30-minute water immersion.

Case 2: The specimens were prepared by blowing 50 times on each side at a temperature of 20°C and 5°C, and after air-dry curing at the same temperatures for specified periods, tested at those temperatures by 30-minute water immersion.

Case3: Pursuant to the Low Cost Pavement Procedure [1] (the specimen was prepared by blowing 50 times on each side at 20°C, left in the mold and soaked for 24 hours in a drying oven at 110°C, and then immediately underwent blew 25 times on each side at room temperature. After soaking it overnight, it was tested at 60°C by 30-minute water immersion).

Table2: Results of Marshall Stability Test

Test Case	Preparation/curing temperature	Curing period	Mashall test temperature	Item		
				Density (g/cm^3)	Stability (kN)	Flow value (1/100cm)
Case-1	20°C	3 days	60°C	2.370 (2.355)	3.0 (Crash)	26 (-)
Case-2	20°C	2 hours	20°C	2.375	3.0	22
		3 days			5.4 (3.0)	27 (28)
		7 days			6.0	28
		28 days			10.0	36
	5°C	2 hours	5°C	2.277	4.6	33
		3 days			5.5	32
		7 days			5.9	33
		28 days			8.1	33
Case-3	20°C/110°C	24 horurs	60°C	2.420 (2.460)	11.30 (3.9)	27 (21)

*Number in parentheses is the volue of the Existing cold mixture.

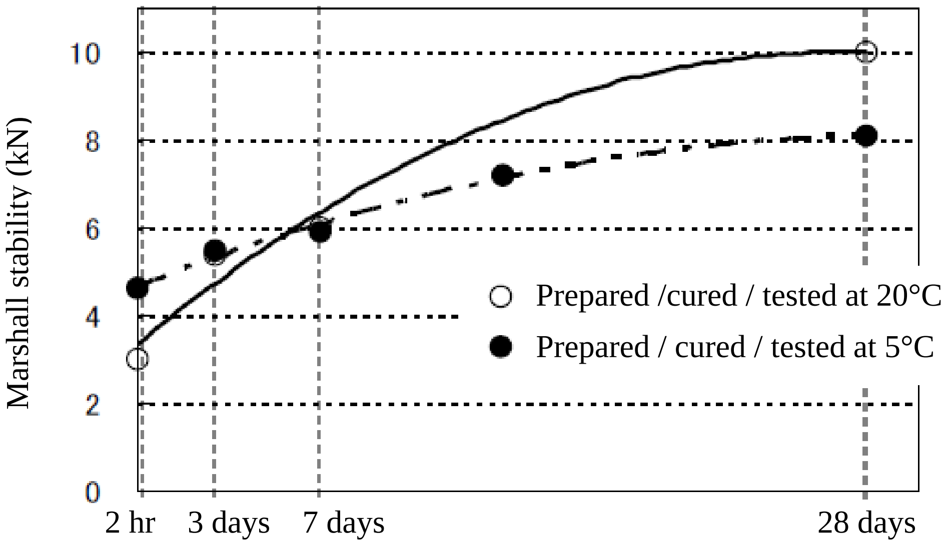

Figure2: Change in Marshall Stability with Time by Preparation, Curing and Test Temperature

These results show that,

1) 2.0kN to 3.0kN of Marshall stability at 60°C can be obtained.
2) About 5.0kN of Marshall stability at 20°C can be obtained after curing at 20°C for 3 days, and about 10.0kN after curing for 1 month.
3) Even at a low temperature of 5°C, development of the strength can be expected.
4) At least 10.0 kN of stability can be obtained in the method indicated in the Low Cost Pavement Procedures.

4.2 Effect of Water

As possible effects of water, we assumed the effect of rain water after the application and application in the rain, and conducted Marshall stability test under the following 3 conditions.

The test results are shown in Table 3.

Case 1: The specimen was prepared by blowing 50 times on each side at 20°C, immersed in water at 20°C for 1 day, and after air-dry curing at 20°C for 2 days, tested at 20°C.

Case 2: After immersing the mixture in water at 20°C for 1 minute, the specimen was prepared by blowing 50 times on each side at 20°C, and after air-dry curing at 20°C for 3 days, tested at 20°C.

Case 3: The specimen was prepared by blowing 50 times on each side at 20°C, and after air-dry curing at 20°C for 3 days, tested at 60°C by 48-hour water immersion.

Table3: Effects of Water

Conditions for preparing and curing test specimens		Density (g/cm^3)	Stability (kN)	Residual stability (%)
Case 1	Assuming rain water immediately after application	2.380	8.0	140 Note 1)
Case 2	Assuming application in the rain	2.335	12.3	216 Note 1)
Case 3	Assuming long-term effect of water	2.370	8.8	293 Note 2)

Note 1): Residual percentage to the stability at 20°C of Conditions 2 in Table 2, after curing at 20°C for 3 days.
Note 2): Residual percentage to stability at 60°C of conditions 1 in Table 2

These results indicate that, in the cold mixture concerned, development of the stability is promoted by the presence of water, and at the same time, the cold mixture concerned has good water-resistance.

4.3 Raveling Test

The specimen was prepared with a roller compactor targeting the density of the Marshall specimen with blowing 50 times on each side at 20°C, and after air-dry curing at 20°C for 7 days, a raveling test[2)] was conducted using cross chains. The test results are shown in Table 4. For reference, test results of hot mixture (dense-graded asphalt mixture (13F)) and existing cold mixture are also indicated.

Table4: Results of Raveling Test

Item / Type	Density (g/cm^3)	Wear (cm^2)
Cold mixture concerned	2.375	1.7
Hot mixture	2.370	1.3
Existing cold mixture	2.355	Collapse

These results indicate that the wear resistance of the cold mixture concerned against chains is comparable to that of the hot mixture.

4.4 Storage Stability

To examine the storage stability of the mixture by storage period, we packed 40 kg of the mixture in each bag and piled up 10 bags at 20°C, and 14, 28, and 42 days after then, prepared the test specimens by blowing 50 times on each side at 20°C. After air-dry curing at 20°C for 7 days, we conducted a Marshall stability test at 20°C. The test results are shown in Table 5.

Table5: Results of Storage Stability Test

Storage period (days)	Immediately after mixing	14		28		42	
Loading position	–	Top	Bottom	Top	Bottom	Top	Bottom
Density (g/cm^3)	2.373	2.370	2.356	2.352	2.336	2.347	2.336
Compaction degree (%)	100	99.9	99.3	99.1	98.4	98.9	98.4
Stability (kN)	3.0	2.9	2.8	2.7	2.8	2.9	2.7

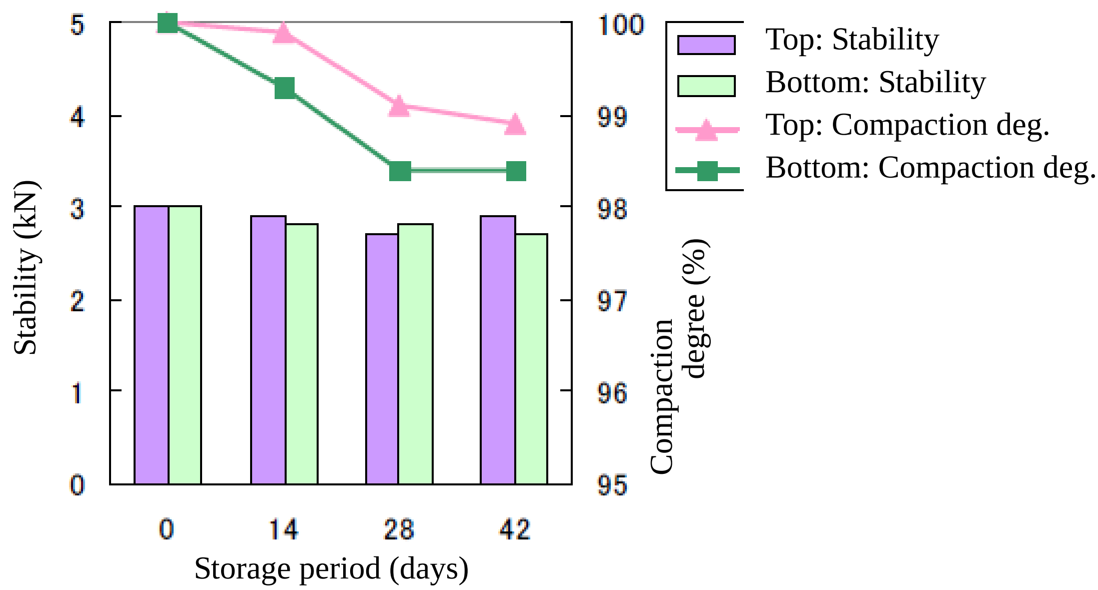

Figure3: Stability by Storage Position and Degradation of Compaction Degree with Time

As seen in these results, although the compaction degree decreased by approximately 1.5% with the passing of storage time, very little degradation of the stability was observed. Based on these results and the results of visual observations of the mixture, we assume that the mix can be stored for about 1 month when 10 bags each containing 40 kg are piled up, though it may depend on ambient temperature and other conditions.

5 EVALUATION OF DURABILITY IN FIELD

Using the cold mixture concerned, we performed repairs of pot holes on heavy traffic roads and snowy and cold regions in the snow-melting season, and followed them up by visual observations. Representative examples are shown below.

5.1 Examples of Application to Heavy Traffic Road

Using the cold mixture concerned packed in bags that had been stored for 2 months after mixing, we performed repairs of several depressions with cracks that had occurred on wheel paths in road sections of uninterrupted flow on a national highway, and one repair of a depression that had developed on a wheel path in an intersection in Saitama Prefecture, and followed them up.

5.1.1 Repairs of Depressions with Cracks (National Highway in Saitama Prefecture)

The spots to be repaired were depressed and had cracks, as shown in photograph 2, and the repairs required 0 to 40 mm-thick pavement with tapering. The construction proceeded as follows: the spot to be repaired was cleaned, and asphalt emulsion was applied; after the asphalt emulsion was decomposed, the mixture was spread and leveled, and the compacted with a vibro plate; the traffic was resumed immediately. Photograph 3 shows the condition immediately after the traffic was opened.

Even though partial scattering and flow were partly observed until 6 months passed from the construction, all the repaired sites were in good conditions. At the point when 9 months passed, reflection cracking had occurred at some spots as shown in Photograph 4. However, at other sites, the conditions were almost the same as 6 months after the repair, though the flow progressed.

Photograph2: Spot to be repaired, a depression with cracks

Photograph3: Traffic was opened immediately after repair

Photograph4: 9 months after repair

5.1.2 Repair of a Depression in an Intersection (National Highway in Saitama Prefecture)

The spot to be repaired was, as shown in Photograph 5, where vehicles running on both highways crossing there pass and turn right/left, and depressed with a maximum depth of about 40 mm. The construction was performed in the same way as above, and the traffic was resumed immediately after the repair. Photograph 6 shows the condition immediately after the traffic was opened.

Until 6 months after the repair, a flow with a maximum rutting depth of about 20 mm occurred, but no stripping and scattering were observed. At 9 months after the repair, the condition was almost the same as at 6 months, though the flow progressed to some degree.

Photograph5: Spot to be repaired, a depression in an intersection


Photograph6: Traffic opened immediately after repair


Photograph7: 9 months after repair

5.2 Examples of Repairs of Pot Holes on Snowy and Cold Regions in Snow-Melting Season

Early in March, the snow-melting season, we repaired a pot hole on a national highway in Yamagata Prefecture and pot holes in Yonezawa City, Yamagata Prefecture, using the cold mixture concerned which had been stored in bulk for 10 days after the mixing, and followed them up.

5.2.1 Repair of a Pot Hole (National Highway in Yamagata Prefecture)

The spot to be repaired was a pot hole about 70 cm in width, 120 cm in length, and 15 cm in depth that developed on a wheel path, as shown in Photograph 8. Since the pot hole there had caused problems in vehicle traffic, it had been repaired repeatedly with existing cold mixture. However, since melted snow was always in it and traffic was heavy, most of the applied repair material was scattered within around 1 week after the repair. The construction was performed, as shown in Photograph 9, by charging the cold mixture concerned loaded in bulk on a truck into the pot hole with water and beating the mixture with the back of shovels. Since a long-term traffic control was impossible due to heavy traffic, compaction with vibro plate was not performed, and the traffic was resumed immediately after the repair (Photograph 10).

Photograph 11 shows the condition at 3 months after the repair. Even though consolidations of about 10 to 15 mm were observed, a good condition was maintained with no scattering.

Photograph8: Spot to be repaired, a pot hole with water

Photograph9: Repair work

Photograph10: Traffic resumed right after repair

Photograph11: 3 months after repair

5.2.2 Repairs of pot holes (Yonezawa City, Yamagata Prefecture)

As shown in Photograph 12, the spots to be repaired were large and small pot holes consecutively developed on a wheel path. The construction was performed by charging the cold mixture concerned loaded in bulk on a truck into the pot holes (Photograph 13) and compacting well with a vibro plate, and the traffic was opened right after the construction.

Photograph 14 shows the condition at 3 months after the repair. No scattering was observed and a white line was drawn on the repaired spots. A little flow was found, and one of the causes for this appears to be lowered stability due to the water that came into the mixture and filled the voids, creating the same conditions as the presence of excessive binder, since the cold mixture concerned was charged and compacted in places where water was pooled.

Photograph12: Pot holes to be repaired
in snow-melting season

Photograph13: Scene of repair work

Photograph14: 3 months after repair

6 CONCLUSION

The cold mixture introduced herein has the following characteristics: (1) storage and application at normal temperature are possible as with existing types of cold mixture, (2) 2 – 3 kN of Marshall stability at 60°C, which cannot be measured in the case of ordinary cold mixture, can be obtained, and (3) good water-resistance as the presence of water promotes development of the strength. When applied to the maintenance and repair of heavy traffic roads and snowy and cold regions, this is more durable than existing cold mixture, and considered to be a useful material for repairing the spots that require immediate repair, such as pot holes during the snow-melting season since it can be used in the presence of water, though that is not really desirable usage in view of the potential flow. We hope that this cold mixture will contribute to safe driving of vehicles, etc.

REFERENCES

Fukushima, et al, 1982, *The actual situation of cold laid asphalt mixtures about maintenance of pavement*, Japan Highway Public Corporation technical information, Japan.

Japan Road Association, 1979. *Low Cost Pavement Procedures* , Japan.

Japan Road Association, 2007. Pavement investigation / testing method handbook , Japan.

Katano, et al, 1970, A normal temperature mixture by cutback asphalt-style method of construction, Hoso 5-8, Japan.

Miyashita, et al, 1988, *Development of a cold laid asphalt mixture for the winter season for wet case pothole repair*, Japan Road Conference Proceedings, Japan.

Takeda, et al, 1985, *About applicability to a heavy traffic road of various cold laid asphalt mixtures*, Japan Road Conference Proceedings, Japan.