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Influence of Anti-Cracking Agent on Asphalt Pavement with Cement-Treated Base

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Abstract—**The cement-treated base(CTB) has been used successfully to address ever-increasing traffic volume and at locations where subgrade quality is poor, however, one of the main distresses for asphalt pavement with CTB is reflective cracking. An innovative construction methods[Continuous Construction Method(CCM)] was proposed in this paper to mitigate the premature cracking originated from the CTB. The CCM differs from the traditional construction method in the construction process. Traditionally, the CTB need to be cured for 3- to 7- days after paving to secure strength, this procedure was canceled in CCM and the asphalt mixture was supposed to be paved immediately after the construction of CTB. Anti-cracking agent was developed and added into the cement stabilized base materials to prolong the hydration process and initial setting time of the base materials, thus providing sufficient time for paving the asphalt concrete layer and guaranteeing the asphalt mixture being paved and compacted before the cement stabilized materials hardened. In addition, micro-expansion materials generated from the pozzolanic reaction between cement-treated materials and anti-cracking agent could contribute to reducing the porosity of CTB and the contraction space for drying shrinkage and temperature shrinkage. In this paper, the influences of anti-cracking agent on setting time of cement paste, basic mechanical property and shrinkage property of cement-treated materials were analyzed, and the generation of ettringite from cement system was investigated from the microscopic perspective by the scanning electronic microscope (SEM). The test results indicated that the cement treated materials with anti-cracking agent have good micro-expansion and densification performance, which significantly reduces the shrinkage caused by the temperature and humidity change, improves the pavement performance of CTB and prolongs the roadway service life. Additionally, test roads were constructed and contrasted to verify the anti-cracking effectiveness of CCM. Pavement performance was monitored for 4 to 5 years after construction. During the evaluation period, both laboratory and field tests were conducted to obtain the strength, bonding condition and cracking rate data. The results showed a superior compositive anti-cracking performance of CCM. Bond strength and shear strength between the surface layer and the base layer were improved.**

Keywords—**cement-treated base; reflective cracking; anti-cracking agent; continuous construction methods**

I. Introduction

The asphalt pavement with cement-treated base(CTB) has the advantages of high strength, sound flatness and good anti-fatigue performance, and has become the main pavement structure of the high-grade highway in China [1,2]. However, premature failure caused by sever cracking of the CTB often occurs, with cracks reflecting to the surface and leading to the complete failure of these sections shortly after they were opened to traffic [3-5]. Reflective cracking in the asphalt pavement with CTB is originally derived from the shrinkage cracking in the cement-treated materials, which can be divided into three categories: autogenous shrinkage (shrinkage resulting from the hydration of the cement), dry shrinkage and temperature shrinkage [6,7]. K.P George and H.E. Bofinger studied the shrinkage cracking phenomenon extensively and concluded drying causes the majority of the shrinkage [8,9]. Under the repeated vehicle and temperature loads, these cracks in CTB reflect to the top of the surface layer. Reflective cracking is the main crack form of asphalt pavement with CTB [10]. Rainfall infiltration through cracks combined with repeated traffic loading will cause washout of underlying materials through a pumping action. Loss of pavement base support usually results in rapid pavement deterioration in terms of localized failure zones, settlement of pavement surface, cracks, and potholes. These pavement conditions shorten the life of the roadway [4,11]. Therefore, it is necessary to improve the anti-cracking performance of asphalt pavement with CTB to reduce the propagation of reflective cracks into the surface layer.

Over the years much work has been performed regarding reflective cracking in asphalt pavement with CTB. In German, the design specifications of 1986 states that when the thickness of the asphalt overlay is greater than or equal to 140mm, whatever the grassroots thickness is, as long as the compressive strength of grassroots over 2MPa, the grassroots must be pre-cutted with longitudinal seams and transverse joints. In Austria, a microcracking concept originated to use several vibratory roller passed to the cement treated base at a short curing stage, to create a fine network of microcracks. The researchers reported this "microcracking" process prevents the development of large stress cracks [12,13]. In the UK, engineers use a polymer network with high tensile strength as a middle layer between the CTB and asphalt layer to prevent the crack propagating upward [14,22]. In Japan,

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mixture of cement and special asphalt emulsion is used in stabilization to prevent water evaporating, and the water in asphalt emulsion can be used by the hardening of cement, so that the contraction coefficient decreases with the increase in the dose of asphalt emulsion [15]. Some other researchers use geotextile fabric or rubber asphalt intermediate layer between the surface layer and CTB as stress absorbing layers to restraint pavement cracks [11,16].

A lot of studies on the anti-cracking measures of CTB have also been conducted in China. By using the framework dense structure, Dai and Jiang approved that improving the grade of cement stabilized aggregates can significantly reduce its shrinkage [17,18]; Xu added grid debris in the cement-stabilized soil so as to enhance the crack resistance performance of the road foundation [19]. By adding reinforced materials or improving the composition of cement-treated materials, those methods above show certain effect on the prevention of cracks, but most of them require substantial additional steps in the construction process. There are still improvements in economic, construction simplicity, and curing cracks.

While numerous approaches to minimize shrinkage cracking and prevent reflective cracking exist, this paper discussed a controlled continuous construction methods(CCM) by adding low-cost additives. Adding additives is more straightforward. At present, the widely used expansive agent is sulphoaluminate expanders, whose source of expansion is ettringite (C3A • 3CaSO4 • 32H2O). The results of Huang and Lv’ s study showed that cement-stabilized aggregate base can improve the primary road performance by adding Tetraguard AS20 reducing agent (produced by Shanghai) which has a good prospect, however, it increased the direct costs to some extent [20]. In this paper, the chemical waste phosphogypsum was used to develop a low-cost anti-cracking agent which can make the cement-treated materials have a micro-expansion and increase its densification. The principle of this technology is to stimulate pozzolanic reaction to occur between the phosphorus gypsum (calcium sulfate dihydrate) and lime by using alkaline binder lime. Substances generated by the pozzolanic reaction, AFt(3CaO • Al2O3 • 3CaSO4 • 32H2O) and AFm (3CaO • Al2O3 • CaSO4 • 32H2O) has a certain amount of expansion and densification, making the shrinkage caused by the temperature and humidity change reduced significantly and achieving the purpose of reducing road base cracking, thus improving the pavement performance of CTB and prolonging the roadway service life. At the same time, the addition of anti-cracking agent to the base materials prolongs initial setting time and hardening time of cement treated materials so that CCM can be implemented. The asphalt mixture was paved and compacted before the cement stabilized materials hardened, the surface layer and base layer were compacted and bonded tightly as a whole that higher pavement structural capacity against loads and cracks was obtained.

II. Background

Traditional CTB construction requests the CTB must be adequately cured after finishing, allowing cement to hydrate and the cement-aggregate mixture to harden. The newly constructed base should be kept continuously moist (by lightly watering or misting) for a 3- to 7-days period, or a moisture-retaining cover or curing compound can be placed over the CTB soon after completion [2,21]. Afterwards, the wearing surface asphalt mixture can be constructed. This traditional construction method could have some drawbacks. Firstly, the engineering properties of the exposed CTB are vulnerable to be influenced by temperature and climate variation, for example, the large temperature fluctuation between day and night could induce temperature contraction cracking in CTB during the curing period, rainfall may bring about more sever deterioration. Secondly, although means have been taken to keep the newly constructed base moist, it is inevitable that the base moisture changes frequently, alternation of dry and wet state can cause the shrinkage crack. Thirdly, the separately constructed surface layer and base layer can not be effectively bonded to bearing loads as a continuous whole, showing a poor resistance to reflective cracking and shear slip at the interface. Worse still, the surface of CTB can easily be polluted during the curing period for human factors and environmental factors, and these are hidden dangers to the bonding quality between the surface layer and base layer.

In this project, researchers worked on the implemention of a continuous construction method, exploring the possibility to cancel the curing period of CTB and construct the surface layer and base layer coherently. As soon as the construction of CTB was finished, the afterwards procedure to pave the asphalt mixture should be conducted and finished in 8- to10-hours, just as the initial setting time of the cement treated materials that can be extended by the anti-cracking agent. Compared with the traditional pavement construction, CCM has made some crucial changes. Firstly, the asphalt concrete layer was paved and contracted before the initial setting of base materials, making the mutual infiltration process begins at the beginning of the cement stabilized materials hydration. Under the action of the vibration rolling compaction on surface layer, aggregates of the asphalt mixture and cement stabilized mixture embedded and squeezed into each other a certain depth, forming a mutually staggered contact surface at the interlayer, better friction resistance and bond property can be acquired then. Secondly, the CTB was covered instantly by the hot asphalt mixture which isolates the CTB from the external environment and prevents water evaporation and rainfall influence. A high temperature field was formed by the hot asphalt mixture in which the CTB can be cured by nature. The cement hydration reaction was accelerated by the high temperature field, therefore, rapid increase in the strength of CTB eliminates the cracks caused by temperature stress in traditional curing period for a slower strength growth. Thirdly, a continuous bonding condition between layers indicates that the surface layer has to inherit the resistance from the base layer when the low-temperature contraction occurs for the asphalt mixture has a bigger temperature shrinkage coefficient than base mixture. So the strain energy generated in the contraction of the surface layer was transformed in the process of overcoming the potential energy of the base layer, the base layer can act as a temporary block to the surface cracking and the surface layer can obtain a better low temperature stability. Fourthly, both the prime coat and tack coat can by omitted in CCM, as well as the 3- to 7-days curing period, construction duration and cost can by reduced greatly this way. Moreover, the elimination of pollutions between layers enables the CCM constructed road to obtain better bonding condition and road quality.

III. Laboratory Materials and Tests

A. *Materials*

The anti-cracking agent is mainly composed of phosphogypsum and lime, and its physical state is gray powder. The anti-cracking agent was used to replace part of the cement in accordance with a certain proportion during the test.

The 42.5R ordinary Portland cement was used in this study, whose physical and mechanical properties are compliant with the regulations. Fly ash was from Hubei Province (Class I). Graduation of the aggregates 10-30mm gravel: 10-20mm gravel: 5-10mm gravel: chip was 10:20:25:45. The mix proportion of the cement-stabilized macadam cement: fly ash: gravel was 4:16:80. The mixture gradation screening result is shown in Table I.

TABLE I. MIXTURE GRADATION SCREENING

Grain Diameter /mm	31.5	19	9.5	4.75	2.36	0.6
Passing Rate /%	100	90.7	72.1	30.7	18.3	10

B. *Testing Results and Discussion*

1) Setting Time Test

The setting time was tested according to ASTM C191-08 “Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle”. A Vicat apparatus was used to test the setting time for different anti-cracking agent addition. Vicat needle penetration tests were conducted, with a needle diameter of 1.13 mm and a probe weight of 300g. The test ring and the glass bottom plate were glued to avoid leakage of paste. The initial setting time was determined when the Vicat needle penetrated 25mm. The final setting time was the time when the needle did not sink visibly into the paste. The testing temperature was 20℃, and the relative humidity was 95±5 percent. Tree tests were performed for each percentage of anti-cracking agent to examine setting time.

TABLE II. SETTING TIME OF CEMENT PASTE

Test Number	**Additive Type**	**Agent Addition /%**	**Standard Consistency/ %**	**Setting Time (h)**	
				Initial Setting	***Final Setting***
1-1	Blank	0	25.8	2.78	4.10
1-2	Anti-cracking agent	1.5	25.3	3.00	5.93
1-3	Anti-cracking agent	3	25.4	4.75	7.08
1-4	Anti-cracking agent	4.5	25.2	7.18	10.25
1-5	Anti-cracking agent	6	25.4	11.16	14.00
1-6	Anti-cracking agent	9	25.3	15.75	19.50

Table II gives the results of setting time test obtained for cement paste at different anti-cracking agent contents. Results indicate that the anti-cracking agent can obviously extend the setting time. The increasing trend of setting time become clearer as more anti-cracking agent was added to the mixtures. When the content of anti-cracking agent reaches 6 percent, compared with the blank test, the growth rates of the initial setting time and final setting time are about 301.80% and 241.46% respectively, which are longer than those without anti-cracking agent.

The anti-cracking agent can play a role in set-retarding and water-reducing, extending the molding time and improving the working performance of cement-treated materials. The more the content of anti-cracking agent is, the longer the setting time is. This is because the anti-cracking agent replaces part of the cement when molding cement paste, the quantity of cement is reduced, and the water-cement ratio is increased, which is negative to the hydration of cement. At the same time, the soluble phosphorus and fluorine in phosphogypsum react with the calcium in an alkaline environment, and the insoluble reactants $Ca_3(PO_4)_2$ and CaF_2 are easily to be adsorbed in the diffuse double layer on the surface of monomineralic, reducing the permeability of the electric double layer for water molecules. Then the rate of AFt and C-S-H gel generated slows down, and so is the rate of spatial network structures formulated by the cement-based system. As a result, the initial setting time and final setting time of the cement is extended. The more the anti-cracking agent content is, the slower the rate of cement hydrates, and the longer the initial setting time and final setting time.

2) Mechanical Property Test

The unconfined compressive tests were performed in accordance with ASTM D5102-09. The optimum moisture content and maximum dry density of cement stabilized macadam was tested at first as the weight parameters for specimen. The standard weight of a single specimen m_0 is calculated as follows:

$$m_0=V\times\rho_{max}\times(1+\omega_{opt})\times\gamma\times(1+\delta)\qquad(1)$$

TABLE III. MECHANICAL PROPERTY OF CEMENT-STABILIZED MACADAM BASE

Code	**Agent Addition/%**	**Maximum Dry Density /%**	**Optimal Water Content/%**	**Compressive Strength /MPa**		**Tensile Strength /MPa**	
				Curing for 7d	*Curing for 28d*	*Curing for 7d*	*Curing for 28d*
2-1	0	2.368	5.10	4.46	5.27	0.45	0.65
2-2	3	2.368	5.50	4.53	5.56	0.46	0.62
2-3	6	2.368	5.50	4.41	5.20	0.46	0.69
2-4	9	2.368	5.50	3.82	5.14	0.43	0.74
2-5	12	2.368	5.50	3.81	5.08	0.40	0.76

Where V is the volume of the specimen which is determined by the size of the specimen ($\Phi 150 \times 150$); ρ_{max} is the maximum dry density; ω_{opt} is the optimum moisture content; γ is the standard degree of compaction which is set as 98%; δ is the loss rate of the specimen during the test and its range is from 0 to 2%.

Put the prepared mixture into a prefabricated test mold with an upper and lower pad, and then impose pressure to the uppper pad with a hydraulic pressure testing machine, maintaining the loading rate 1*mm/min* until the specimen can be molded. Spun the specimen off from the test mold by ejector after two hours. Seale the specimen with a plastic bag and put it into a curing room with standard conditions (ambient temperature of 20℃±2℃ and relative humidity higher than 95%). In the last day of the curing period, the specimen was removed out and soaked into water with the temperature of 20℃±2℃. In order to ensure the accuracy and representativeness of the experimental data, 13 tests were performed to determine compressive and tensile strengths of each anti-cracking agent percentage. Table III shows the compressive strength and tensile strength of cement-stabilized macadam.

3) Shrinkage Property

Shrinkage property is an important factor which should be considered in road designing and construction process. The smaller the dry shrinkage and temperature shrinkage are, the better the road qualities on cracking resistance and integrity. The rate of shrinkage is used to characterize the cracking resistance of the material in this paper.

The shrinkage test specimen's size was 100*mm*×100*mm* ×400*mm* (Length × Width × Height). Since the shrinkage of spacemen is significantly affected by temperature and humidity, all specimens were prepared and kept under the standard conditions (ambient temperature of 20±2℃ and relative humidity of 50%±2%). The molding method for shrinkage test specimen is a little bit similar to what has been described in the last section. The difference is that the test mold for specimen is a cube instead of a cylinder. Three repeated trials were conducted for different agent addition.

a) Analysis of Dry Shrinkage Test

Specimens for drying shrinkage test were cured for 7 days under the condition of temperature 20℃±2℃ and relative humidity higher than 95% and soaked into water on the last day as well. After that the length of the specimens were measured for the first time and were deemed as the initial length. Then, they were removed to a shrinkage room with the condition of temperature 20℃±2℃ and relative humidity 60%±5%. In the shrinkage room, the beam type specimen was placed in the shrinkage apparatus, with two micrometers at each end of the specimen. So the shrinkage caused by the loss of moisture was measured through the change of dial gauge.

Table IV and Figure 1 show the dry shrinkage results at different anti-cracking agent contents. In fact, an increase in the anti-cracking agent results in a decrease in the measured dry shrinkage. Anti-cracking agent has a significant effect on the reduction of the shrinkage of the semi-rigid base. It can be concluded from Table IV that the average dry shrinkage rate of the cement gravel aggregates mixed with anti-cracking agent No. 1 is 20.6% less than that of No. 0. The average dry shrinkage rate of No. 2 is 23.4% less than that of No. 0. The average dry shrinkage rate of No. 3 is 14.2% less than that of No. 0.

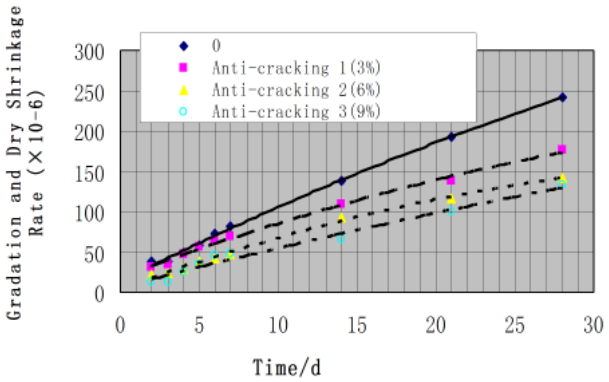


Figure 1. Dry shrinkage rate at different anti-cracking agent contents.

b) Analysis of Temperature Shrinkage Test

After seven days of curing as what has described, specimens for temperature shrinkage test were placed in an oven being dried to constant weight with the temperature of

TABLE IV. DRY SHRINKAGE RATE AT DIFFERENT ANTI-CRACKING AGENT CONTENTS

Time/day		**2**	**3**	**4**	**5**	**6**	**7**	**14**	**21**	**28**
Gradation and Dry Shrinkage Rate /×10-6	0	38.8	37.7	49.6	57.9	73.6	82	138.5	193.4	241.8
	Anti-cracking 1(3%)	31.5	34.9	47	55.8	63.5	68.9	109.8	137.5	176.3
	Anti-cracking 2(6%)	22.4	24.1	29.3	38.4	42.2	46.9	93.4	116.8	142.2
	Anti-cracking 3(9%)	13.5	12.8	24.8	34.9	46.2	47.2	65.1	100.2	132.1

TABLE V. TEMPERATURE SHRINKAGE RATE AT DIFFERENT ANTI-CRACKING AGENT CONTENTS

Gradation	**Average Temperature Shrinkage Rate in each Temperature Section /×10-6**								
	-30℃~ -20℃	***-20℃~ -10℃***	***-10℃~ 0℃***	***0~ 10℃***	***10~ 20℃***	***20~ 30℃***	***Average***	***Max-average (0~30℃)***	***Min-average (-30~0℃)***
0	12.9	13.78	17.53	13.32	13.45	12.06	13.84	12.94	14.74
Agent 1 (3%)	9.62	12	14.32	11.62	11.52	11.35	11.74	11.5	11.98
Agent 2 (6%)	9.58	11.03	13.56	10.54	8.56	8.34	10.27	9.15	11.39
Agent 3 (9%)	8.13	8.46	11.23	9.42	8.41	7.27	8.82	8.37	9.27

105 ℃. These dry specimens were put into a high-low temperature test chamber, where cooling rate, temperature and humidity were controlled precisely. Shrinkage apparatus were also used to measure the temperature shrinkage.

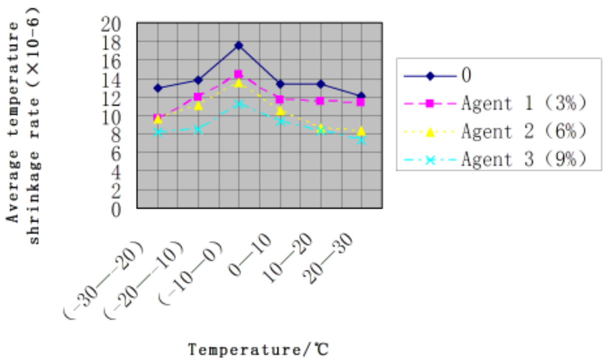


Figure 2. Temperature shrinkage rate at different anti-cracking agent contents.

Table V and Figure 2 present the temperature shrinkage rate in each temperature section over the first 28 days for all specimens at different anti-cracking agent contents. It should be noted that each point on the curves represents the average results for the three tested replicates. The curves clearly indicate that the shrinkage decreases as the anti-cracking agent content increases. Therefore, the temperature shrinkage of cement-stabilized macadam can be improved obviously by adding anti-cracking agent. Figure 2 also shows that the curve of the temperature shrinkage rate has a peak value at the test temperature range (-30~30℃), no matter how much agent is added. The peak value occurs at the range of 0 to 10℃, which indicates that semi-rigid base is prone to shrinkage cracking in the cold winter.

The shrinkage rate of the CTB with anti-cracking agent is much lower, regardless of dry shrinkage or temperature shrinkage, i.e. both the dry shrinkage and temperature shrinkage cracking resistance of the CTB with anti-cracking agent are better than those without anti-cracking agent. The results show that, the CTB with anti-cracking agent has a good micro-expansion and densification, so the shrinkage space of the cement-treated materials caused by the change of temperature and humidity can be greatly reduced, which can essentially reduce and prevent the pavement cracks so as to extend the road life.

4) Strength Formation and Anti-cracking Mechanism

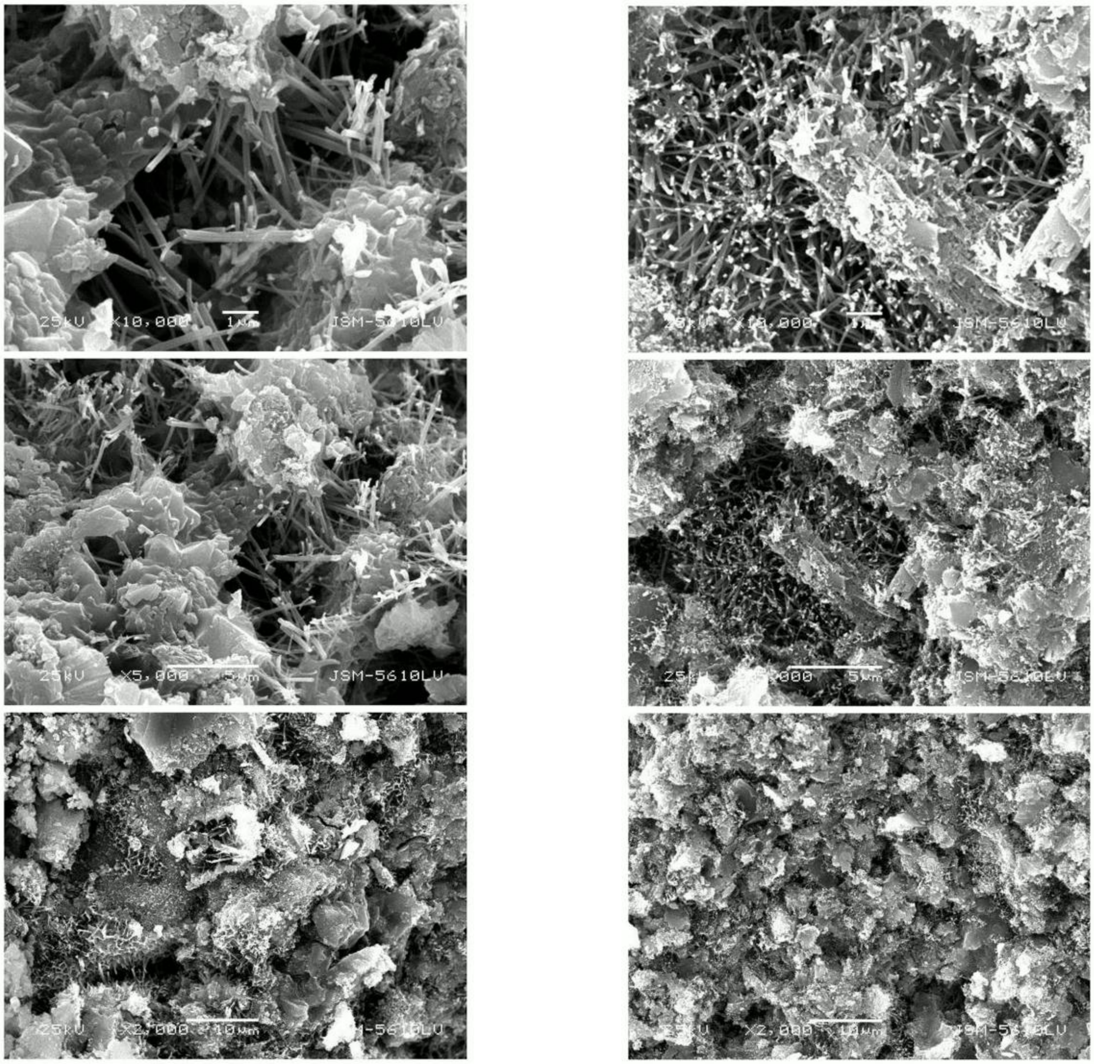
Appropriate amount of anti-cracking agent addition changes the medium environment of cement hydration, making the initial chemical reaction in cement-stabilized macadam mainly base on the pozzolanic reaction, and promoting the formation of ettringite (AFt). The needle-like AFt fills the space relying on the gel that formed by the reaction products of pozzolanic reaction hydrated calcium silicate (C-S-H) and hydrated calcium calcium aluminate($3CaO \cdot Al_2O_3 \cdot nH_2O$), constituting the skeleton to provide for the early strength. Chemical reaction continues between the hydrated calcium calcium aluminate(3CaO •

$Al_2O_3 \cdot nH_2O$) and ettringite(AFt), generating the rodlike AFm ($3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 32H_2O$). Finally, most of AFt transformed into AFm, AFm and the left AFt further cross-linked each other so that the mixture contacted into an even more compact overall with high strength. With the increasing number of AFt and AFm crystal generated, density of the cement stabilized gravel mixture was greatly improved, and the porosity was reduced. What's more, these crystals can not only consume a certain degree of moisture, they also have significantly expansion and densification properties, which can effectively reduce the contract space of the semi-rigid base material when temperature and humidity change, and then prevent shrinkage and cracking caused by the excessive contraction.

5) SEM Analysis

The untreated specimens with and without anti-cracking agent are conducted by SEM test 28 days after molding. Each kind of spacemen was scanned in three dimensions, 1 *μm*, 5 *μm* and 10 *μm*. The results are shown in Figure 3.

In Figure 3(b), needle-like or columnar ettringite and rodlike AFm cross-link each other, together with the C-S-H gel, running through the cement paste, while there is just a little AFt and AFm generated and distributed unevenly in Figure 3(a). The pores in the binder cement-stabilized crushed stone with anti-cracking agent are much less than that without anti-cracking agent, so under the same conditions the expansion pressure that the liquid forces on the specimen with anti-cracking agent is obviously smaller. Thus, the anti-cracking agent has a function of shrinkage-compensating and may prevent cracking effectively.



(a) Without anti-cracking agent (b) With anti-cracking agent

Figure 3. SEM of different specimens.

IV. Testing Road Verification

The performance of CCM constructed pavement was compared with that of the conventional constructed pavement. The pavement structure of the test roads consisted of 6.5cm dense-graded asphalt concrete with hot-mix asphalt mixture, tack coat, 30cm of cement-treated base(5.5% of cement by weight),and natural subgrade. The dosage for anti-cracking agent was 5% of the cement weight. The unconfined compressive strength(UCS) tests and interlaminar shear strength tests were conducted. The long-term cracking was detected and reported.

A. *Compressive Strength Test*

Cores were taken from the test roads at the age of 7days, 28days, 90days, 180days, respectively. As shown in Table VI, the average compressive strength of cores from the CCM road are all higher than that of the cores from conventional road at the early, middle and late stages. The CCM can improve the durability and service life of the road.

TABLE VI. LONG-TERM COMPRESSIVE STRENGTH OF CEMENT-TREATED BASE

Code	**Anti-cracking agent**	**Compressive strength/MPa**			
		7 days	***28days***	***90 days***	***180 days***
3-1	without	4.48	5.28	5.93	6.33
3-2	with	4.52	5.56	6.12	6.41

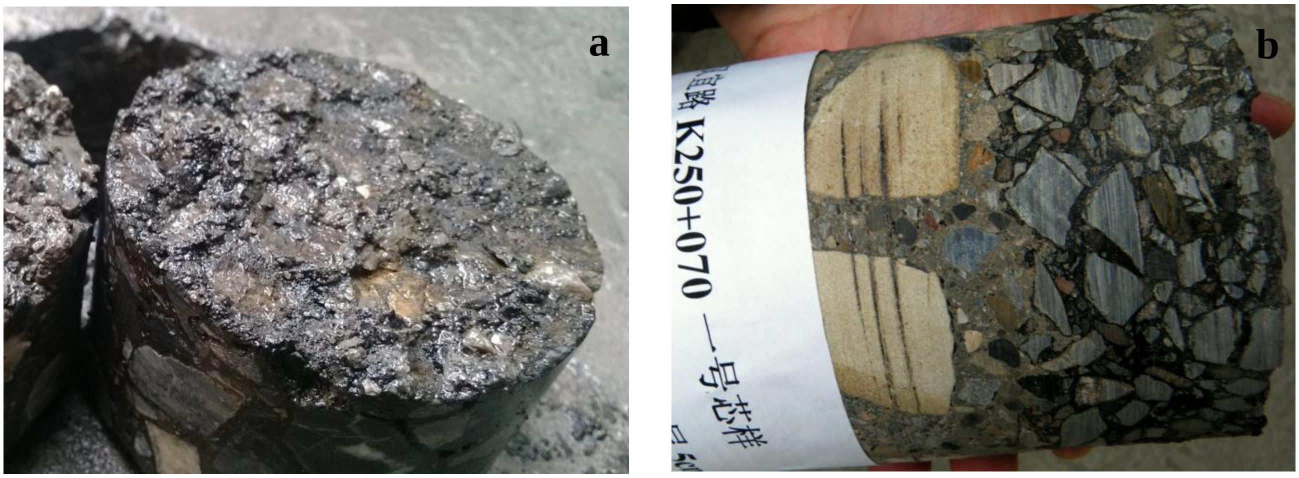


Figure 4. Interface bonding condition.

B. *Bonding Property Test*

Take cores at the age of 1 year[Figs.4(a) and 4(b)]. Based on observation of cores from different road areas, a smooth interface between the surface layer and the base layer can be founded from the cores taken from conventional constructed road[Figs.4(a)]. While layers of cores taken from CCM constructed road were bonded to a continuous whole, with the depth of 15mm embedded and squeezed to each other[Fig.4(b)]. The shear strength of cores are shown in Table VII. The test results show that cores taken from CCM constructed road has higher shear strength than those taken from conventional constructed road, with an significantly increase of 35%.

TABLE VII. BOND PROPERTIES BETWEEN THE SURFACE LAYER AND BASE LAYER

Core site	**With anti-cracking agent**			**Without anti-cracking agent**		
	Site 1	***Site 2***	***Site 3***	***Site 1***	***Site 2***	***Site 3***
Core length /cm	36	34	34	34	33	35
Shear strength /MPa	0.85	0.79	0.80	0.57	0.60	0.58
Average shear strength/MPa	0.81			0.58		

C. *Anti-cracking Performance*

To compare and contract road performance of the testing roads, a survey on the cracking has been taken(Table VIII), which indicates the CCM constructed road has a superior performance than the conventional one. On the conventional constructed roads, about 30~100 transverse cracks were

TABLE VIII. ROAD PERFORMANCE DETECTION FOR TESTING ROADS

Testing road	Pile mumber	Width/m	Flatness/mm	Deflection value/0.01mm	Friction coefficient	Crack number per km	Paving age/year
Paved by continuous construction method	Liangjiang Road K18-19	9	3	36	47	1	4
	Liangjiang Road K63-64	9	4	40	42	4	4
	Hanyi Road K250-K251	9	3	38	48	3	5
Paved by conventional method	Liangjiang Road K18-19	9	4	56	42	45	4
	Liangjiang Road K63-64	9	2	49	43	77	4
	Hanyi Road K250-K251	9	9	58	43	96	5

detected per kilometer, while only 1~4 transverse cracks were detected per kilometer on the CCM constructed roads, decreasing the cracking rate by 90% at least. In addition, when taking cores at the cracked areas, the conventional constructed CTB disintegrated during the coring and extracting process. But an entire core still can be extracted from the CCM constructed road as the AC portion remained firmly attached to the base layer during the coring operation, the AC layer is bonded very well to the CTB layer.

V. Conclusion

Based on findings from this study, the following conclusions can be made.

- By adding appropriate amount of anti-cracking agent, shrinkage properties and mechanical properties of cement-treated materials can be improved significantly. The suggestion volume of addition is 4%~6% of cement by weight, which may fluctuate with geographic and material properties and should be determined by laboratory test before construction.
- The anti-cracking agent can prolong the setting time of cement-treated materials to 8-10 hours, which extends the casting time and provides enough time precondition for operating the continuous construction method(CCM).
- The AC layer can be bonded with CTB layer better by CCM. The detection on performance of testing road shows that the combination of anti-cracking agent and CCM has practicability and effectiveness on preventing reflective cracking.

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[The combination of anti-cracking agent and CCM has practicability and effectiveness on preventing reflective cracking.]

Jianmin Zi

[Although laboratory and field tests have proved that the interlayer bonding were enhanced, there still needs a lot of research on the bond mechanism and its influencing factors to achieve more comprehensive benefits from CCM.]

Lei Mao

[The construction process of testing roads shows that the CCM can be implemented via effective organization and control, which is of remarkable time efficiency and makes it possible to open road to traffic ahead of schedule.]

Tao Hu

[As the low-cost chemical waste phosphogypsum could be used as the main raw material for anti-cracking agent, there is almost no impact on construction costs.]