Application of In-situ Cold Recycled Subbase in Highway Maintenance in Loess Area

Liping Liu\textsuperscript{1,2}, Wanfeng Liu\textsuperscript{1,2}, Yang Yang\textsuperscript{1,2}, Jianbo Guo\textsuperscript{1,2}, Caixia Bao\textsuperscript{3}

\textsuperscript{1}School of Civil Engineering, Longdong University, Qingyang, Gansu, 745000, China
\textsuperscript{2}Provincial Key Laboratory of Loess Engineering Properties and Application in Universities, Qingyang, Gansu, 745000, China
\textsuperscript{3}Qingyang Highway Administration of Gansu Province, Qingyang, Gansu, 745000, China

*Corresponding author’s e-mail: 635502138@qq.com

Abstract. This paper studies the application of the in-situ cold recycled subbase technology of the asphalt pavement with using cement as an additive. From the two aspects of analysis and practical application, the construction process of in-situ cold recycling of asphalt pavement is studied specifically. Moreover, combined with the engineering practice, and through the introduction of the cold recycled construction process and the analysis of the test results, this paper expounds the specific construction process of the cold recycled subbase, and points out the existing problems and matters needing attention in the project construction.

1. Introduction

At present, the problems that road construction is restricted by market economy are more and more prominent, and the requirements for benefit of road construction investment are also getting stricter. To make the limited resources exert the maximum efficiency, the cold recycled technology is a new technology which has been widely applied recently and gradually attracted people's attention [1].

In-situ cold recycled subbase technology is an operation process, which makes full use of the original pavement structural materials (including asphalt surface layer material and part of the base material, that is, the surface layer + base layer) to repeatedly use after milling planer processing, and if necessary, adding some new aggregate, a certain proportion of stabilizer (cement, lime, etc.), and an appropriate amount of water at a certain ratio to in-situ complete the material milling, crushing, mixing, paving and rolling forming in a natural environment, so as to form a new base or subbase with required performance strength requirements [2].

The cold recycled technology of the asphalt pavement using the cement stabilized old asphalt mixture to form the pavement base layer (subbase layer) can not only utilize the waste materials of the old pavement to save the road building materials, but also solve the space occupation and environmental pollution of the waste materials. In-situ cold recycled also has the advantages of simplifying construction process and saving construction period. Therefore, cold recycling technology can save investment, increase direct economic benefits, and ensure the ecological environment to obtain social benefits, which is an environmentally friendly new type technology that benefits the country and the people [3].

This technology is mainly applied to the existing road surface structure that needs to be renovated and rebuilt. The level of construction technology and the quality of the construction have a great
influence on the quality of the cold recycled road [4]. Based on the construction and application of the local cold recycled subbase in the Loess area of eastern Hebei, the construction process, quality control process and key points are illustrated by examples.

2. Engineering Applications

2.1 Engineering construction process

The G211 line K321+800~K331+300 section (8.2km length) is a research project of the first cold-recycling construction technology in Gansu Province. The project is located in Qingcheng County, Loess area of eastern Hebei, with a total scale of 94300m², 18cm thick in-situ cold recycled subbase layer. The construction process is shown in Figure 1.

| Additive | Old road milling, crushing | New aggregate |
| --- | --- | --- |
| Water | Mixing new and old material | Paving recycled layer |
| Rolling and forming | Flatting with a grader |
| Pavement maintaining |

Figure 1. Construction process of cold recycled subbase layer in situ

2.2 Raw material performance analysis and quality requirements

This project is a cold recycled of the road base layer, and it is necessary to use the original road base material for new cement stable base construction. In order to determine the gravel grading after the original road base milling, and ensure that the requirements of the cold recycled base design grading are met, the old road base material screening test is necessary.

The milling material of the original pavement base layer is taken for indoor screening test. The sample was placed in an oven at 105 °C ± 5 °C to dry to constant weight, and the aggregates were sieved one by one according to the order of the mesh size. The dry sieve method is used to accurately weigh the remaining amount on each sieve above the 4.75mm sieve hole, and then the remaining amount on each sieve below the 4.75mm sieve hole is determined by the water washing method, thereby determining the gradation composition of the old base layer milling material.

The mixture of the old road surface of K321+000~K322+200 on National Highway 211 was sampled and sieved. The natural moisture content of the road milling material was 4.1%, the plasticity index was 7.8, and the screening test results are shown in the Table 1. According to the screening results, the pass rate of the comparison specification indicates that the original road surface milling material is well graded, and all kinds of particle compositions are within the scope of the specification of cement stabilized materials. When cold recycled construction, the original pavement base layer
milling material can be directly used. There is no need to add new grades of gravel. The cold recycled resurfacing project adopts a full-depth cold recycled method, which does not adjust the gradation.

Table 1. Milling test results

| Screen size (mm) | 37.5 | 31.5 | 19 | 9.5 | 4.75 | 2.36 | 0.6 | 0.075 |
|------------------|------|------|----|-----|------|------|-----|-------|
| Milling material | 100  | 98.8 | 87.8 | 55.9 | 27.5 | 14.4 | 5.8 | 1.7 |

The project uses cement produced by Pingliang Conch Cement Factory with good performance and reliable quality. In order to ensure the quality of the project construction, the incoming cement samples are tested for strength, fineness, consistency, setting time and stability to ensure that the quality meets the standard requirements. It is advisable to use ordinary silicate cement with a strength grade of 32.5 or above. It is forbidden to use metamorphic cement due to external influences. The strength and stability of cement in each period should meet the requirements of the specification; the initial maintaining and final maintaining time of cement should be determined according to the needs of the construction site. When entering the site, the cement should have product certification and test list; transportation and stacking should pay attention to waterproof and moisture-proof, and stack it neatly when entering the warehouse; P.C32.5 ordinary silicate cement is generally used for simultaneous opening and construction sections. The used water is clean, non-polluting and potable.

This project uses one German imported 2000 Wirtgen cold regenerator, two 22-ton vibratory roller, one 18-21-ton road roller, one 180-type grader, and three sprinklers.

2.3 Construction preparation

2.3.1 Measurement, line setting out and initial road shaping. For the section of the cold recycled construction, the midline measurement and setting should be carried out before construction. One level point is set every 200m along the side line to facilitate the control of the elevation. The leveling point should be set at a fixed position that is not easily damaged by people or vehicles.

Before the cold recycling construction, the original road surface disease should be treated. For the surface pavement, subsidence, pit and other diseases, the gravel or gravel that meets the water stability specifications is used for treatment, rolling and refurbishing to achieve the road elevation or design requirements. For the section of the cold recycled subbase construction, the road elevation control is difficult, and the material backfilling is generally performed only on the low part of the original pavement.

2.3.2 Mix proportion design of cold recycled mixture. One month before the cold recycling construction, the original road surface should be milled (the depth is the same as the design depth), and four sets of the original pavement mixture mixed with cement are taken for material screening test and compaction test to determine the mixture ratio.

The reconstituted mixture compaction test was carried out in the specified test drum, and the water content-dry density relationship curve was drawn to determine the optimum water content and maximum dry density of the recycled mixture. The compaction test of the recycled mixture was carried out according to the cement dosages of 2%, 3%, 4%, 5%, and 6%. The cement and the cold recycled mixture were uniformly mixed according to the above ratio, and the optimum water content and maximum dry density of the mixture were determined by vibration compaction. According to different cement dosages, the corresponding test pieces with different maximum dry density and optimum water content were prepared, and the unconfined compressive strength test of the recycled mixture was made after 6 days of pavement maintaining and 1 day of water immersion. The test results are shown in Table 2 and Table 3.
Table 2. Summary of the results of the cold recycled subbase layer compaction test results

| Cement dosage (%) | 2.0% | 3.0% | 4.0% | 5.0% | 6.0% |
|-------------------|------|------|------|------|------|
| Maximum dry density (g/cm³) | 2.252 | 2.263 | 2.279 | 2.288 | 2.291 |
| Optimum water content (%) | 7.0 | 7.1 | 7.1 | 7.3 | 7.3 |

Table 3. Summary of unconfined compressive strength of cold recycled subbase

| Lime dosage (%) | Cement dosage (%) | Test piece dry density (g/cm³) | Test piece compaction (%) | Water absorption (%) | Average value Rc (MPa) | Standard deviation S (MPa) | Deviation coefficient Cv (%) | Strength representative value (MPa) |
|-----------------|-------------------|-------------------------------|--------------------------|---------------------|------------------------|--------------------------|-------------------------------|-------------------------------|
| 3.0             | 2.0               | 2.162                         | 96.0                     | 7.9                 | 1.53                   | 0.10                     | 6.38                          | 1.40                          |
| 3.0             | 3.0               | 2.161                         | 95.5                     | 6.7                 | 1.79                   | 0.15                     | 8.27                          | 1.60                          |
| 3.0             | 4.0               | 2.174                         | 95.4                     | 6.5                 | 2.26                   | 0.14                     | 6.11                          | 2.09                          |
| 3.0             | 5.0               | 2.187                         | 95.6                     | 6.3                 | 2.54                   | 0.15                     | 5.91                          | 2.35                          |
| 3.0             | 6.0               | 2.188                         | 95.5                     | 7.2                 | 2.78                   | 0.12                     | 4.21                          | 2.63                          |

3. Cold recycled subbase layer construction in test section

3.1 Pre-construction training
Cold recycling technology is a new process. Therefore, before the start of construction, 35 employees of the mechanical operators, construction workers and migrant workers who participated in the construction were trained. After training, everyone should know what to do. And for each link, arrange specially-assigned person to take charge; From the gridding and line setting → cement transfer → unloading bags → cement paving → work area laying, etc., each process has fixed personnel for operation; Small machine and tools (sickle for bag broken, iron hook, trolley for construction setting out, measuring scale, etc.) are prepared to make the construction go on smoothly.

3.2 Summary of test section
According to the requirements, the project has made 4 test sections according to different additive ratios: 3% cement, 3% lime 150m long; 4% cement 150m long; 4.5% cement 150m long; 5% cement 150m long, total 600m long test segment. After 7 days of pavement maintaining, the unconfined strength of 4.5% cement content reached 3.6Mpa, and the unconfined strength of 5% cement content only reached 3.3Mpa, so the strength of 4.5% cement content meets the design requirements. Considering the economic, reasonable and construction difficult factors, this project uses 4.5% cement content as the cement reconstituted base layer cement dosage. The construction results of the test section are summarized as follows:

3.2.1 Water content. The maximum dry density of the mixture is 2.283g/cm³, and the optimum water content is 7.1%. The water content during construction should be slightly larger than the optimal water content of 1-2%, and the natural moisture content of the original pavement is between 4.5% and 5%.

3.2.2 Milling depth. During the construction of the test section, it was found that the original pavement base was gravel ash, the thickness was only 15cm, and the original design milling depth was 18cm. The soil in the subgrade was milled into the mixture, causing the mixture to contain too much soil, so that the mixture was mixed. The gradation did not meet the design requirements. The bidding
section was revised with the project office and the supervision unit to modify the milling depth to 15cm. When the cold regenerator was milling, the two cutters were overlapped by 10cm to ensure that there is no omission between the two cutters.

3.2.3 Random detection frequency. Check the cutter head once and the milling depth once (take the average of the 3 points) per cut (50m length); the water content of each working surface is measured once after the two cutters lapped joint of 150m-200m (or half width of the road surface).

3.2.4 Compaction times. After the cold regenerator cutter lifting and working 50 m, the roller followed for rolling compaction. When rolling, first time was static pressure, and then use 18-22 tons of vibratory roller (2 sets) to vibrated roll 5 times. After the adjacent two cutters or half of the road surface was lapped, leveling machine was used to level. Before leveling, based on the actual situation, if the water dispersion of the mixture was too large, it needed to be watered before leveling. After leveling, the static pressure of the 18-21 ton three-steel wheel roller compactor should be used for 5 times, or the road can be crushed 3 times with a rubber roller of 16 tons or more to compact and flat the road surface. After the completion of the two cutters lapped joint or the completion of the half-width road surface, the compaction degree is measured, and the pavement is maintained after the compaction degree is qualified. Otherwise, the pressure is required to make the compaction degree meet the requirement, and the compaction degree is controlled to be 97% or more. The construction control indicators of the test section are shown in Table 4 below.

| Name | Natural moisture content of pavement | Milling depth | Milling width | Regenerator walking speed | Rotor speed | Two cutters overlap width | Working length |
|------|-------------------------------------|---------------|---------------|--------------------------|------------|--------------------------|----------------|
| Numeric value | 4.5%-5% | 15cm | 200cm | 8m/min | 120-150 | 10cm | 150-200m |

4. Cold recycled bottom base layer construction technology and quality control

4.1 Gridding and line setting
Calculated the amount of cement per square meter of mixture based on the maximum dry density of the mixture. Since the working width of the cold regenerator is 2m, the lines were set at every 2m wide from the middle line of the road to the roadside during the half-length construction. The paving area of each bag of cement was calculated according to the amount of cement per square meter, and the 2m wide line was drawn into grids horizontally. We used a 2m × 5m square grid, and paved 3 bags of cement per grid.

4.2 Cloth cement bag, broken bag, paving cement
Calculated the number of cement bags placed in each grid based on the grid setting. After the cement placed in each grid was broken, the cement was evenly paved in the square with tools, and the cement paving must not exceed the grid line.

4.3 Cold regenerator operation
When the cement was paved for 50m, the cold regenerator started to work. For the control of the milling depth, when the cold regenerator gone out 20m, a technician taken three points on each side of the mixture to measure the depth. When the average value is greater than or less than the design value of 1cm, it is necessary to report the thickness adjustment to the operator in time. After the adjustment, continued the inspection according to the above method until it was qualified. The thickness of the looseness after mixing is between 23cm and 25cm, and the looseness coefficient is between 1.5-1.6.
When the second cut started to overlap, it was necessary for one worker to remove the mixture every 5m for the first cutting edge to ensure that the regenerator was accurately overlapped.

4.4 Water content adjustment
The water content of the on-site mixture was controlled according to the optimum water content provided by the laboratory. Under normal circumstances, the compaction effect is better when the water content of the construction is slightly larger than the optimum water content of 1%-2%. After cold recycled completed a working surface, it was necessary to check the water content of the site. The water content does not need to be adjusted around the optimal water content. If the detection is less than or greater than the optimal water content, the operator should be notified in time to adjust the water content until it reaches or close to the optimum water content. The water should be even and the water consumption of milling should be strictly controlled. The milling should be kept as constant as possible, and the suitable speed should be controlled. The side of the milling should be cleaned and there should be no loose particles. According to the design plan, to the appropriate depth, the milling should not be too deep, and do not leave the interlayer.

4.5 Rolling and leveling
When the cold recycled mixer came out 20m, the first single drum vibratory roller compactor followed the first static pressure. After the roller came out 30m, the second single drum vibratory roller began to vibrate and crush.

When the lapping of two cutters of regenerator was finished, and the number of rolling passes reached the requirement, the grader started to level the road. Before leveling, when the water dispersion on the surface of the mixture is too large, it needs to be leveled based on the situation after watering. When the grader is working, the progression should be stable, cannot be paused until accomplish, and the cross slope of the road arch should be made according to the design requirements.

After the leveling machine leveled, the three-steel wheel roller crushed immediately. When crushing, the center of the road should be crushed to the roadside, and the corner should be crushed from the low to the high. When the roller is crushed, the progression should be smooth. When moving forward and backward, the direction should be in well control. It is strictly forbidden to turn around insitu and fast swerve. After 5 times of rolling, the degree of compaction was measured at every 50 m. After the design was completed, the road was covered for maintaining. If the compaction degree was not qualified, the rolling was continued until the compaction degree was qualified. The roadbed after the completion of the vibration compaction number is not suitable for vibration rolling, as the vibration rolling will cause the crushed roadbed to be destroyed.

4.6 Pavement maintaining
After the end of the final pressure, sprinkle water for maintaining. There are two ways for pavement maintaining: one is to cover the road with geotextile for pavement maintaining after the final rolling and watering. During the maintaining period, the number of vehicles running on the cold recycled subbase layer should be strictly controlled after construction to ensure the formation of the cold recycled base layer to meet the design requirements. The other way is to construct cement stabilized base in the cold recycling construction at the same day. On the same day, the cold recycled and the subbase layer are simultaneously formed, but only the subbase layer is maintained, so that the maintenance cost of the cold recycled base layer can be saved and the progress of the project can be improved.

5. Summary of local cold recycling practice

5.1 Economic Analysis of Cold Recycled Subbase
Compared with the gravel ash-filled base layer of the same thickness, the subbase layer paved with cold recycled technology costed 1.50 yuan/m² of excavated old oil skin (transport fee includes) and
16.20 yuan/m² of sand gravel, cement 7.40 yuan/m², labor costed 1.82 yuan/m², machinery costed 5.04 yuan/m², a total of 31.96 yuan/m²; total cost per square meter of cold recycled base layer is 24.60 yuan/m² (calculated by engineering actual calculation). Compared with the gravel-doped sub-base layer per square meter, the cold-recycled base layer saved 7.36 yuan. If smart cement spreader construction is used, the cost will be lower.

5.2 Attention should be paid to the construction of cold recycled on site

Widely used in structural layers of different roads. Under normal circumstances, the aggregate of the old road structural layer material is more than 5cm and the content of larger than 40% and smaller 80% can be utilized by the in-situ cold recycled technology. If the aggregate content of the material above 5 cm is too low, it is necessary to add a suitable graded fine aggregate according to the screening test to form a well-graded skeleton, and the dense structure increases the strength of the mixture.

It is used in construction with large traffic volume and without interrupting traffic. According to the original road conditions, half-width construction and half-width traffic can be adopted to avoid long-term interruption of roads. According to the characteristics of the project and the actual traffic conditions of the road vehicles, the project uses a half-width pavement closure construction and a half-way traffic safety closure scheme. In order to ensure the safety of driving, construction machinery and personnel, full-time safety personnel are required to do a good job of traffic closure, protect equipment safety and smooth roads, and release construction information and construction announcements in relevant media before the start of construction.

On-site cold recycling construction can use a variety of stabilizers, such as cement, fly ash, lime, etc., depending on the specific situation. The stabilizers may be used either singly or in combination.

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