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Construction Technology of Warm Mix Asphalt Pavement in Cold High-Altitude Areas

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Abstract: With the continuous development of domestic highway construction, highway civil engineering and service level quality have attracted much attention. Good pavement quality and high-quality service make people feel comfortable and smooth when traveling. High-quality pavement can significantly reduce the probability of traffic accidents. At present, there is a direct relationship between pavement quality and pavement construction operations. Carrying out pavement construction operations in cold high-altitude areas requires a reasonable selection of construction equipment and methods. The application of warm-mix asphalt pavement construction technology can ensure pavement quality. Therefore, this paper analyzes the advantages of warm-mix technology, the environmental characteristics of cold high-altitude areas, and construction preparations, and discusses the construction technology of warm-mix asphalt pavement in cold high-altitude areas in detail, to improve the overall road quality of cold high-altitude areas.

Keywords: Cold high-altitude areas; Warm mix asphalt; Pavement construction technology

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1. Introduction

At present, the expansion of highway construction has reached cold high-altitude areas, infusing new vitality into the development of road networks and economic progress in cold high-altitude areas. Cold high-altitude areas have significant temperature differences between day and night, thin air, low temperature throughout the year, and long duration of low temperature, which requires higher and stricter construction technology. In highway construction, asphalt concrete pavement construction is a typical example. When applying asphalt concrete pavement in regions with both extreme cold and high altitudes, it is necessary to take corresponding measures to ensure the durability of the pavement, thereby effectively prolonging the operational lifespan of the road.

2. Advantages of warm mixing technology

Warm mixing technology is a new technology in which temperature is between regular temperature mixing and hot mixing. In the case of the same raw materials, compared with hot mixing, the temperature change technology's low temperature and compaction temperature should be lowered by 20°C–50°C. The key to warm mixing technology is to improve the operability of asphalt mixture construction through physical and chemical methods without damaging the normal function of the road. The evaluation of the warm mixing process is mainly based on the following two aspects: (1) there is sufficient operating cooling range; (2) all indicators meet the relevant technical indicators and technical requirements of pavement materials [1].

(1) Achieving manageable pavement quality: Warm mix technology can improve the compressive strength of warm mix asphalt mixture, increase the rolling time of actual construction, and make the compactness of asphalt concrete meet the standard requirements. At the same time, compared with hot mixing, the aging speed of asphalt in the warm mixing process is significantly reduced to extend the road's overall durability.

(2) Regulating construction timelines: In the case of a significant temperature difference between day and night, the application of warm mixing technology can still ensure the mixing and laying of asphalt concrete, resulting in increased asphalt concrete production. The construction time in cold high-altitude areas is extended.

(3) Managing investment wisely: In the case of long-distance transportation, the mixing volume of warm mixing technology is doubled, and the compaction requirements can still be guaranteed. At the same time, due to the lower heating temperature of the aggregate, the mixing output can be increased by about 20%, thereby reducing investment costs.

3. Environmental characteristics of cold high-altitude areas

Due to the harsh climate conditions in cold high-altitude areas, the altitude is high, the air is thin, the sunshine time is long, the radiation is significant, the temperature is relatively low, and the temperature difference between day and night is significant. The rainfall in high-altitude areas is significantly affected by terrain. The rainfall decreases gradually from the edge of high-altitude areas to the depths of high-altitude areas. The rainfall in the central river valleys is abundant. The surface vegetation mainly includes deciduous broad-leaved forests, alpine grasslands, subalpine shrubs, alpine meadows, and tundra. Permafrost is widely distributed in high-altitude and extremely high-altitude areas. Glaciers are in extremely high-altitude areas, and glacier changes are expected. Most lakes in high-altitude areas have high salt content, and there are few freshwater lakes [2].

(1) Significant diurnal temperature range and low annual average temperature: The air in cold high-altitude areas is thin and dry. In a year, the maximum radiation emitted by the sun can reach 190 kcal/km^2, more than twice that of other areas. Cold high-altitude areas receive much sunlight during the day, the surface heats rapidly, and the heat dissipates quickly at night. The lowest temperature in a day can be lower than 0°C, and the highest can reach 30°C. The annual average temperature is low, and the annual change is small. For example, compared with the plains at the same latitude, the average temperature in January and July is 15°C–20°C lower on the Qinghai-Tibet Plateau. Compared with regions at the same latitude, high-cold and high-altitude regions are affected by surface heat, so the climate is the driest and coldest, and the surface wind speed is the largest.

(2) Less affected by human factors: Due to the climate, fewer people are in cold high-altitude areas. For a long time, the impact of human activities on the ecological environment in high-latitude regions has been almost negligible. Especially in the central part of the Qinghai-Tibet Plateau, there are very few human activities, so people's production and life have relatively little interference with the environment in these areas. In addition, restricted by other factors, there are no large-scale human activities in cold high-altitude areas, so the development of cold high-altitude areas is still in its

infancy. The influence of regional ecosystems is increasing.

4. Particularity of pavement construction in cold high-altitude areas

Road surface rolling is challenging to form in cold high-altitude areas. In these areas above 2800 m, due to the influence of the microclimate in mountainous areas, the temperature is low, and the construction period of the hot-mix asphalt concrete pavement is less than two months. It often encounters rain and snow. The interference of weather factors. During this period, the construction work surface under the sun during the day meets the construction requirements. However, it is challenging to meet the requirements of the "Technical Specifications for Asphalt Pavement Construction" at night. Under such a temperature environment, the compaction process of traditional hot-mix asphalt mixture is relatively complicated, quickly leading to huge pores, and seriously affecting road pavement's durability. In addition, due to the long transportation route of mountainous roads, under normal conditions, the temperature of the mixing and discharging material has been dramatically reduced when it is transported to the paving area. During the construction process, the temperature of the asphalt mixture is higher than that of the general area, which leads to the difficulty of roller compaction of asphalt concrete. If, to ensure the on-site temperature of the mixture, a significant increase in the heating temperature of the aggregate and asphalt during mixing will lead to accelerated aging of the asphalt, thereby increasing the risk of road quality control [3].

Cold high-altitude areas have poor temperature conditions as these areas have high latitudes, most are over 2,000 meters high. According to research, the temperature drops significantly with the increase in altitude. According to calculations, the temperature generally drops by 6°C for every increase of 1,000 meters above sea level, and the temperature drops by 1°C for every increase of 150 meters in individual areas. In addition to the low annual average temperature in high-altitude areas, there are also apparent daily temperature changes. Summer is rainy and hail, and winter is dry, cold, and windy, which lasts for a long time.

5. Preparatory work for warm-mix asphalt pavement construction in cold high-altitude areas

The traffic volume in cold high-altitude areas may not be high, but the harsh natural conditions of the plateau, such as intense ultraviolet rays, significant diurnal temperature differences, freeze-thaw cycles, and strong winds on the plateau surface, are likely to aggravate the conventional diseases of the pavement structure. Therefore, it is essential to make reasonable choices regarding pavement materials and to incorporate thoughtful design and construction techniques to mitigate the occurrence of pavement-related problems. During the design stage, it is crucial to consider unfavorable natural conditions, such as hydrogeological and climate factors specific to the project area, along with the known issues related to the previous projects. This allows for the selection of appropriate design criteria that ensure the pavement functions as intended with extended service life.

(1) Basic design: The pavement base layer serves as the primary load-bearing component within the pavement structure and also serves the crucial function of distributing the wheel load pressure from the surface layer to the underlying structure, essentially acting as the "link" between these two layers. The design of the base course takes into account various factors, including the road's intended function, the magnitude of traffic loads it will bear, and the prevailing hydrogeological conditions. It involves a comprehensive assessment that entails comparing successful existing projects and carefully selecting the appropriate elements such as inorganic binder stability, aggregates, asphalt compositions, and cement concrete. Ultimately, the aim is to tailor these choices to suit the unique characteristics of

cold and high-altitude areas while ensuring the complete and reliable performance of the base layer. It is important to note that simply replicating the subgrade design used in lower-altitude areas for cold high-altitude areas can lead to a host of issues, including subsidence, soil instability, reflection cracks, shrinkage cracks, and susceptibility to water damage, particularly in permafrost areas. Thus, a more tailored approach is required to enhance crack resistance and overall durability.

(2) Surface design: The pavement surface directly contacts the wheels and the atmosphere, bears the load of the wheels, and is affected by adverse factors such as rainfall and ultraviolet rays. In addition to considering the conventional bearing capacity and fatigue durability in the design of the surface layer in cold and high-altitude areas, it is necessary to pay attention to the freezing and water stability, low-temperature crack resistance, high-temperature stability, and anti-aging performance of the surface layer, and to control and prevent peeling, cracks, and aging from the design stage. Solving ruts, potholes, and other issues may improve the pavement's service life.

(3) Equipment selection: Low regional temperature, thin air, and low air pressure are the salient features of cold high-altitude areas. Most of the time, advanced construction machinery and equipment are used when constructing asphalt concrete pavements. Under such regional characteristics, higher requirements for construction machinery and equipment are put forward. In terms of mechanical power, in addition to some mechanical parts that can withstand extreme cold, it is also necessary to choose mechanical equipment that uses diesel as power and configure corresponding supercharging equipment. When using a machine with a motor as the main power, it is necessary to choose a device with a higher driving power than ordinary mechanical equipment to ensure the machine's regular operation in cold and high-altitude areas. In addition, during the outdoor construction of asphalt concrete, mechanical equipment such as asphalt pavers, asphalt concrete mixers, and presses will significantly impact the quality of asphalt concrete construction. Therefore, when configuring this mechanical equipment, it must be based on factors such as the particularity of cold high-altitude areas and the differences in the construction sites of the project selected [4].

6. Construction technology of warm-mix asphalt pavement in cold high-altitude areas

6.1. Stirring of the mixture

In the mixing process of asphalt mixture, batch asphalt concrete mixing plants with closed characteristics are usually used and are equipped with devices for detecting mixing temperature and dust. The mixing station should have a laboratory to test its Marshall stability index (see **Table 1**) as well as the mineral-graded components and raw materials. It should be applied reasonably according to the determined ratio during the mixing process. The heating temperature of the asphalt should be between 150°C and 170°C, the temperature of the aggregate should be between 160°C and 180°C, the outlet temperature of the mixture should be between 140°C and 165°C, and the temperature of the aggregate should be between 120°C and 180°C. Due to the low temperature in cold high-altitude areas, the aforementioned temperature control method usually takes the maximum value. After mixing, it is necessary to ensure that the quality of the asphalt mixture is uniform and that the asphalt evenly wraps the aggregate to avoid graying, agglomeration, and separation of coarse and fine materials. The laboratory conducts daily sampling and inspection of the asphalt after mixing. Once any phenomenon that does not meet the requirements is found, it should be discarded immediately.

Table 1. Marshall stability index test of asphalt mixture

Outcome indicators	Theoretical maximum relative density	Gross volume relative density	Stability (kN)	Void ratio (%)	Voids filled with asphalt (VFA) (%)	Flow value 0.1 mm	Voids in mineral aggregate (VMA) (%)
Volume index	2.437	2.303	10.77	5.4	68.7	29	16.2
Skills requirement	-	-	≥ 8	3.0–6.0	65–75	20–40	-

6.2. Paving the mixture

During the paving process, 1–2 heated vibrating leveling equipment can be used to adjust the paving thickness by itself. The lower and middle surfaces can be constructed using a straight-line method. In surface structures, the equalized beam method can be used. Before paving, the paving route should be set, and the paving platform should be supported with longboards equal to the number of paving layers. When using an infrared thermometer, it should be ensured that the temperature of the asphalt mixture is between 110°C and 130°C and must not exceed 165°C. During use, the paving of the paver must be closely controlled to ensure the uniform operation of the paving.

Moreover, in front of the paver, there must be a transport vehicle full of mixed materials to ensure that there will be enough materials during the paving process. The construction unit should designate a person to inspect the paved surface's width, thickness, plane, and temperature. If there is any unqualified situation, it should be pointed out and dealt with in time. Manual methods should be used for construction in areas where the machine cannot be operated [5].

6.3. Mixture rolling

Asphalt pavement rolling is a critical link in the road construction process, and its construction effect is closely related to the quality of the pavement. Regarding machinery, rubber-wheeled and double-steel-wheeled rollers are commonly used [6]. The tonnage of the double-steel-wheel double-vibration road roller used in the road construction specifications for cold high-altitude areas is 12–15 tons, while the tonnage of the rubber-wheeled road roller is 25 tons. The rolling process of asphalt concrete is divided into three stages: initial pressing, re-pressing, and final pressing, and the temperature is controlled correctly.

(1) Initial pressure: Use a wheeled double-shock roadbed, and roll 1 to 2 times at a high temperature above 110°C.

(2) Recompacting: Use the above two types of rollers for recompacting, and repeat rolling 4 to 6 times at 80°C–100°C.

(3) Final pressure: Double-steel wheel rollers are used for final pressure, and the pavement is statically pressed 1–2 times without exceeding 65°C.

When rolling, it should be noted that the order of rolling should be from low to high at a uniform speed, and the width of adjacent superimposed rolling should not exceed 300 mm. Moreover, in the rolling process, it is necessary to ensure that the mixture does not stick to the wheel, and the method of atomization and spraying can be used to solve the problem. In addition, the road roller must run straight without any movement or cracks. Otherwise, it will directly impact the paved road [7]. Meanwhile, it is not allowed to stop the machine on the newly paved road to add water and refuel to avoid pollution to the road. After the roller is finished working, it should be driven away immediately. Since the paved road surface temperature has not dropped below the natural temperature, it is impossible to stop. Plate compactors or small vibratory rollers are used for work for the road sections that cannot be rolled or rolled by the roller.

6.4. Crack treatment

(1) Vertical: Regarding the treatment of longitudinal construction joints, the edges should be trimmed and cleaned before rolling. When rolling, walk on the compacted road surface and carry out 10–15 m of compaction, compact the newly paved part, and extend to the compacted pavement 10–15 cm so that the longitudinal joints can be compacted entirely [8].

(2) Horizontal: In the treatment of transverse cracks, parallel cracks are more common. Lateral rolling is the first step in solving cracking problems. Place the roller on the compacted mix, extending the new course by 15 cm, moving the new mix by 15–20 cm each time it is rolled until it is entirely on the new course.

6.5. Environmental protection

In the construction of highway sections, it is imperative to institute an excellent environmental protection accountability framework and implement practical measures to prevent environmental pollution and harm resulting from waste, refuse, and noise generated throughout the production and construction phases. The construction activities must comply with the pertinent laws and regulations mandated by the National Environmental Protection Department. Measures implemented within the construction site encompass preventing soil erosion and waste management, mitigating water and air pollution, preserving vegetation, and safeguarding land resources. The overarching objective is to minimize any adverse impacts on the surrounding environment during construction operations.

Throughout the construction process, there will be an enhanced focus on environmental awareness among the construction personnel. The workforce will be organized and directed in accordance with specific regulations to ensure adherence to established protocols in all tasks. There will be proactive efforts to promote the realization of "safe and compliant" projects, bolster oversight of engineering endeavors, foster a favorable working environment, and implement a strategic layout for engineering projects [9]. Management of equipment and raw materials will be intensified, with machinery and materials arranged systematically to guarantee the completion of work tasks while minimizing material wastage. Following the construction phase, collaboration will be fostered with local government bodies and the general public to facilitate the restoration of cultivated land. Disposal of raw materials and soil from the asphalt mixture will be conducted in a responsible manner, ensuring their transport to designated disposal sites.

7. Conclusion

In summary, various industries in China are developing rapidly, and great progress has been made in road construction in cold high-altitude areas. Warm-mix asphalt technology is a new eco-friendly and environmentally friendly construction technology and a key technology in road construction. Therefore, this paper studies the advantages of warm mixing technology, the environmental characteristics of cold high-altitude areas, and the particularity of pavement construction in cold high-altitude areas. At the same time, it also discusses the application of this technology, hoping to promote the development of this technology as well as provide safe and reliable guarantees for road construction.

Disclosure statement

The author declares no conflict of interest.

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