Intelligent Paving and Rolling Construction Technology of Asphalt Pavement

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Abstract. The intelligent construction system of asphalt pavement consists of an intelligent paver, driverless roller, mobile base station, intelligent control program, etc. By installing GPS(BDS)+GNSS satellite receiver, 5G communication chip, microwave communication host, radio signal receiving antenna on the construction equipment and connecting with the processor, switch, program software, and other components set on the equipment, integrate the laser obstacle avoidance radar, infrared temperature detection device, laser ranging sensor and other terminal equipment set on the equipment to realize the intellectualization of equipment function; By running the intelligent control system, mobile 5G communication base station system and construction area acquisition system, command the linkage operation of multiple intelligent types of equipment to realize the intelligent control of pavement construction and meet the requirements of asphalt pavement design specifications.

1. Introduction

With the rapid development of economic construction, the current highway construction technology can not meet the future traffic demand to a great extent. Applying new construction technologies and solutions is very important when significant progress has been made in pavement materials and design.

With the rapid development of highway construction, asphalt pavement construction is more and more extensive, and the traditional construction technology and technology are becoming more and more mature [1]. Still, traditional construction technology has some problems that can not be ignored. For example, human factors have a great impact on the accuracy of datum control; Various waves often appear in the paving layer, ponding is easy to form on the pavement, and the flatness of paving formation is poor [2]; Due to the defects of precision control in traditional construction methods, if the precision control is not enough, it will cause less paving, more paving, and uneven layer thickness, and the construction waste is serious; In addition, the gas generated during construction will also cause certain harm to the health of workers. Through 5g + Beidou (GPS) + informatization and the reasonable layout of various sensors and positioning equipment, the objectives of real-time, continuous data collection, transmission, statistical analysis, and information feedback are achieved, the construction process control, overall inspection, and real-time feedback are realized, the pavement construction quality is...
guaranteed, the requirements of refinement and informatization of highway engineering construction are met, and the error caused by human subjective judgment is reduced [3]. This will make the pavement compaction more uniform, reduce over compaction and under compaction, and improve the service life and performance of the pavement. The schematic diagram of intelligent construction of asphalt pavement is shown in Figure 1.

By summarizing the current highway asphalt pavement construction technology and relying on the development of digital and information construction technology, this paper finds out a set of intelligent paving control technology for asphalt pavement construction, realizes the intelligent construction of asphalt pavement, improves the construction efficiency and asphalt pavement forming quality, and reduces the use of workforce and machinery.

Figure 1. Schematic diagram of intelligent construction of Asphalt Pavement.

2. Composition and principle of intelligent construction technology of Asphalt Pavement

2.1 Preliminary preparation

1) Point selection

The points need to be reasonably selected during the preliminary preparation to realize the rational application of intelligent paving technology. The network of control points shall be arranged around the paving area, and the selection of control points shall be 10 cm to 30 cm away from the edge of the road. Because this area is stable, not easily damaged, and has open terrain, it can ensure that the control point network meets the requirements of intervisibility. During the layout of points, the distance between them needs to be controlled between 160m and 200m to ensure the elevation starting point's continuity, accuracy, and stability [4]. In addition, three water datum points should be set in the control network to provide the basis for subsequent resurvey and maintenance of the elevation system. Observation piers need to be established for water datum points, and their buried depth is 0.5m. In order to reduce expenses, elevation control points and plane control points can be arranged at the same point without reducing accuracy.

2) Data acquisition and processing
(1) Survey plane control network. Some control points are measured by GPS static observation, and then the remaining points are encrypted by the total station. (2) Process horizontal control network data. After the field observation is completed, the four sides of the earth should be used to analyze and process the quality of the observation baseline to realize the systematic detection and determination of the baseline quality. (3) Survey elevation control network. In this process, the systematic measurement of three random points can be realized. After completing this part of the survey, the survey of the elevation control network shall be carried out. During the survey period, it is necessary to reasonably plan the survey route in combination with the specific work needs. (4) Process the data of the level control network. After completing the fieldwork of leveling, all data should be tested to calculate the height difference between points and enter the calculation stage after ensuring accuracy. If the calculation results meet the basic requirements, the corresponding elevation points can be obtained.

2.2 Composition and principle of intelligent paving technology

Asphalt pavement paving intelligent consists of an LED display screen, infrared temperature sensor, GPS antenna, terminal host, M12 interface connecting wire, etc [5-7]. Based on the infrared temperature sensor array, the asphalt paving intelligent system collects the temperature data of the whole paving section in real-time to control the temperature segregation of the asphalt pavement; The mixture paving speed is recorded in real-time through the base station and GPS positioning; The temperature data and speed data are released in real-time through the LED display screen, and the paving data are sent to the remote background server computing center in real-time for storage and analysis. The paving operation report is generated regularly.

When unmanned paving construction is adopted, the automatic monitoring components and program system will send instructions to determine the precise position of the paver through the resection method and obtain the coordinates through the 360° prism fixed on the paver pedal; Then, using the data transmission function of the series program system, the three-dimensional coordinate data obtained by the radio station in real-time is transmitted to the receiving system of the control computer in the form of the electrical signal [8-9]. Then, the receiving system of the control computer establishes the model through complex calculation, compares, analyzes, and feeds back the primary coordinates with the data in the established model, gives the elevation information consistent with the model, corrects and corrects the given data, and then simulates the information data through the computer system program, Than feed it back to the leveling controller of the paver. When the construction is in progress, to make the output data accurate and the paved road data accurate, one of the measuring robots must always monitor the specific situation of paving and carry out quality control to make all control parameters meet the design requirements. At the same time, when potholes appear on the original ground, resulting in the inclination of the paver body, the inclination sensor installed on the mast of the system corrects the attitude of the body in real-time so that the attitude of the paver body is always consistent with the design surface, to ensure the stability of the system and truly realize accurate paving. The composition of intelligent paving system is shown in figure 2.
2.3 Composition and principle of intelligent rolling technology

The intelligent monitoring of asphalt pavement rolling consists of a GNSS reference station, dynamic GNSS mobile station, temperature sensor, on-board flat panel display, wireless transmission sharing system, and GSM signal transmission system [10-11]. Asphalt pavement rolling is an important link in the construction process. By installing a high-precision positioning terminal on the roller equipment, the project monitors each area’s rolling times and rolling speed in real-time. It guides the operator to plan the rolling route reasonably through the time's cloud map on the vehicle plate to ensure that the times meet the standard. At the same time, the temperature monitoring sensor is equipped to collect and upload the rolling temperature data in real-time, intelligently remind the areas with rapid heat dissipation, and suggest the management personnel increase the rolling times to ensure the rolling quality. Intelligent rolling technology relies on digital rolling automatic control systems, mainly measurement and automatic control systems. Before construction, convert the design parameters into a data input system according to the design requirements; During construction, according to the pre-input design parameters, the system receives the elevation signal of the measurement system. After data processing, the system controls the compactor during the compaction operation. At the same time, the system real-time compaction parameters throughout the whole process and controls the compaction quality throughout the whole process to find problems in time and make adjustment responses.

The quasi station sends RTK correction data and differential signals to the surrounding in real-time through the radio to provide centimeter-level high-precision positioning reference points for airborne and detection equipment. The automatic compaction control system mainly includes airborne GNSS / laser receiver, GNSS receiver, and controller. During the operation of the compactor, the airborne GNSS / laser receiver simultaneously receives the laser signal and GNSS satellite signal transmitted by the laser transmitter in the measurement system, transmits the signal to the GNSS receiver, obtains the...
elevation position information through the receiver signal conversion and data processing, and then sends the position information to the controller. According to the pre input design parameters, the corresponding proportion of drive control signals are generated to realize the real-time and high-precision control of compaction quality in the process of compaction [12-15].

3. **Intelligent data acquisition system**

3.1 **Data acquisition**
The data acquisition module mainly includes GNSS differential positioning information, asphalt pavement temperature, roller position data, etc. The schematic diagram of data information acquisition system is shown in figure 3.

![Figure 3. Schematic diagram of data information acquisition system.](image)

3.2 **5G wireless transmission module**
The central processor parses and packages the collected data and transmits it to the 5G module through the serial port. The 5G wireless transmission module wirelessly communicates with the 5G service node in the local mobile network base station through the SIM card. It then transmits the data with the Internet through the 5G network according to the transmission protocol. The schematic diagram of the wireless transmission system is shown in figure 4.
3.3 Remote monitoring system

The system remotely monitors the site by viewing and processing the real-time data of asphalt pavement construction transmitted from the construction site [16]. The schematic diagram of the remote monitoring system is shown in figure 5.

3.4 Positioning information

The following table 1 shows the real-time positioning information of the paper on the construction site displayed by the remote monitoring center, including X and Y coordinates, longitude and latitude, elevation, time, and speed information. Through the accurate positioning of construction vehicles, construction vehicles' running speed, and working track. According to the technical code for the construction of highway asphalt pavement, the paver must pave slowly, evenly, and continuously in asphalt paving.

**Table 1. Positioning information table.**

| X coordinate          | Y coordinate          | Longitude          | Latitude          | Altitude          | Speed  |
|-----------------------|-----------------------|--------------------|-------------------|-------------------|--------|
| 4789719.17346788      | 497788.47923245       | 36.1335789658761  | 117.134573898814  | 34.3248348999489 | 0.192  |
| 4789719.17346894      | 497788.47923356       | 36.1335791234765  | 117.134673294893  | 34.3237432590935 | 0.188  |
| 4789719.17346939      | 497788.47923401       | 36.1335792310783  | 117.134837274249  | 34.3243482930805 | 0.195  |
| 4789719.17347102      | 497788.47923531       | 36.1335794500891  | 117.137934893248  | 34.3250343284792 | 0.191  |
| 4789719.17347362      | 497788.47923673       | 36.1335795998231  | 117.137394032324  | 34.3253682478014 | 0.186  |
| 4789719.17347459      | 497788.47923827       | 36.1335796782362  | 117.138732487349  | 34.3254830150233 | 0.201  |
| 4789719.17347537      | 497788.47923941       | 36.133579456213   | 117.138347873748  | 34.3248230480432 | 0.199  |
| 4789719.17347601      | 497788.47924079       | 36.1335798416472  | 117.139384299878  | 34.3274823948924 | 0.193  |
| 4789719.17347732      | 497788.47924135       | 36.1335801232987  | 117.139347832478  | 34.3264329480324 | 0.187  |
3.5 Temperature data acquisition

The temperature data mainly considers the asphalt temperature, including transportation, paving, and compaction. The infrared temperature sensor is mainly used to measure the rolling temperature during the compaction of asphalt pavement. The installation diagram of infrared temperature sensor is shown in figure 6. The measurement principle of the infrared temperature sensor is to detect the infrared radiation intensity emitted by the target to calculate the temperature of the target. The infrared temperature sensor is generally installed in the compaction machinery 10 ~ 15 cm high from the road surface and does not affect the normal operation of the compaction machinery [17]. It monitors the compaction temperature in the construction process in real-time and assists the roller operator in rolling the construction section within the effective compaction temperature range.

![Figure 6. Installation diagram of infrared temperature sensor.](image_url)

3.6 Application of UAV in asphalt pavement intelligent paving system

The traditional asphalt concrete paving construction mostly uses the plug-in thermometer to measure the temperature. During the summer operation, the staff must spot check and track the asphalt mixture temperature in each process on the working surface with a temperature up to 160 °C. Or take photos one by one through a handheld infrared imager for detection, which has some shortcomings, such as the limited number of temperature measurement points, insufficient representativeness, untimely feedback, and so on. The "unmanned airborne infrared detection system" can accurately monitor and calculate the temperature data of asphalt concrete pavement without dead angle and convert it into the infrared image and thermal image video in real-time. Through the gradual combination of different colours, the asphalt concrete paving temperature can be presented intuitively. The use of an "unmanned airborne infrared detection system" has achieved a breakthrough in asphalt paving temperature monitoring from "point" to "surface," which not only improves the detection efficiency but also avoids the long-term high-temperature operation of workers on the road.

4. Advantages and development trend of automatic construction

4.1 Development trend of automatic construction

At present, the main research direction of paver is to tend to large-scale, miniaturization and serialization gradually; Multifunctional and high performance; Intelligent and electromechanical hydraulic integration.

1) Large scale and serialization

Today, the paving width of the paper has reached 15 m, and the maximum paving thickness is 40 cm, which is consistent with the requirements for pavement paving of multi-lane and various high-grade...
expressways at this stage. In the paper series, the paver with a width less than 3.5m is a small-sized machine. The basic width of the small-sized machine does not exceed 2.5m, and the paving width is 1.5 ~ 3.5m. The small paver has the characteristics of flexibility and convenience and is widely used in some special paving projects such as Boulevard and sidewalk. Therefore, the small paver is also one of the development directions of the paver in the future.

2) High performance and multifunction

The paver develops towards large-scale and serialization and actively develops its comprehensive functions, which is also an important development direction in the future. For example, the f41c multifunctional paver produced by the company has the functions of programming and accurate curve paving. The two wings of the hopper can be controlled separately, and the height of the screw can be adjusted quickly.

3) Intelligent, electromechanical, and hydraulic integration

The design technology of mechanical and hydraulic integration is widely applied in the paver. The electro-hydraulic control system of the paver can also effectively reflect the progressive nature of the paver system and the progressive nature of the selected components. The intellectualization of paver control technology is mainly reflected in the following aspects: (1) automatically display the state of paving operation; (2) Automatically control the material level of the feeding system; (3) Implement constant speed control for paving operation; (4) Control the automatic leveling of paver; (5) Monitor the paving conditions in real-time and diagnose the existing faults.

4.2 Advantages of automatic construction

1) Quality control

Process control is an important part of quality control. In pavement construction, 3D technology can collect, transmit, feedback, and control 3D coordinate information in real-time, which achieves the concept of process control and is more effective in quality control than the traditional baseline method [18-20].

2) Highly humanized

The operator no longer needs to operate the machine in the noisy environment filled with thick asphalt smoke and dust under the hot sun and the heatwave radiated by high-temperature asphalt.

3) Safer construction operation

Unmanned driving completely avoids the potential threat to the driver due to the sudden change of the center of gravity when the center of gravity of the whole machine crosses the trailer slope during the transfer of the paver.

4) High intelligence and informatization

Through 3D levelling + infrared temperature control + remote control + driverless application, the pavement data is transmitted to the background in real-time and processed effectively, which is convenient for later management and quality traceability to realize the intelligent informatization of Paver Construction truly.

5) Reduce construction cost

A great effect of an intelligent rolling system is its advantage in construction cost. The intelligent rolling system can save construction costs. Two operators can be saved every month. Due to the lack of quantifiable control indicators for the compacted surface in the compaction process, the traditional compaction process often uses multiple vibration compaction for 1 to 2 times to ensure the compaction of the pavement. The traditional compaction is mostly compacted for 10 to 12 times (2 times of initial compaction, 6 to 8 times of re compaction, and 2 times of final compaction). The compaction auxiliary system technology can realize the accurate control of the number of times, and Re compaction can reduce 1 ~ 2 times and reduce the compaction cost.

5. Application practice of Intelligent Construction Engineering

The first set of driverless intelligent asphalt road paving and compaction equipment developed by tunnel
joint-stock road and bridge group, Sany Heavy Industry, and Shanghai Beidou platform company has completed the first show of "engineering application" in Shanghai Zhujian road reconstruction project. "This construction mainly verifies the practicability of the unmanned intelligent cluster construction technology for 4.5cm AC-16 overlay. The UAV group adopts the intelligent "double machine parallel paving" and unmanned roller group to work together, adopts the combination mode of "2 + 2 + 2 + 1", and is equipped with 2 pavers, 2 double steel wheel vibratory rollers, 2 rubber wheel rollers and 1 double steel wheel smooth roller, Carry out collaborative construction in different regions. The construction mainly adopts four key technologies: paver intelligent construction technology, roller group coordinated construction technology, group control safety technology, and control platform technology, which can ensure that the plane operation accuracy of the equipment is within 5cm and realize millimeter level flatness control. The ground enhanced Beidou satellite positioning and navigation system is adopted in the three unmanned construction equipment to ensure the accuracy of the driving route of the construction equipment, which can be accurate to within 50mm. Through many sensors installed on intelligent equipment, engineers can fully collect the data collected during construction, such as ambient temperature, pavement temperature, rolling speed, etc. Through big data analysis, the construction parameters can be automatically optimized according to different conditions in the future. The Schematic diagram of unmanned rolling is shown in figure 7 and figure 8.

Given the shortcomings of traditional pavement construction management methods, the pavement intelligent construction monitoring system is applied in the pavement construction process of the Kaichun expressway. The pavement engineering installs intelligent monitoring equipment for the mixing, transportation, paving, and rolling links and transmits the construction data of each link in real-time to the remote cloud computing center through a wireless network for storage, calculation, and analysis display the on-site construction situation in real-time. The pavement intelligent monitoring system of the Kaichun expressway has been applied in the test section, and the overall application is much better than the traditional management means. By applying an intelligent monitoring system, the project manager can reduce the frequency of leaving the site, comprehensively master the construction data through the mobile terminal, save the project labour cost, indirectly eliminate rework, and reduce the construction cost. The overall construction quality of the project has been improved through the monitoring and early warning control of the whole pavement construction process. In addition, the data traceability function of the monitoring system also provides a data analysis basis for the decision-making scheme of transportation and nutrition protection period of the Kaichun expressway.

**Figure 7.** Schematic diagram of unmanned rolling.

**Figure 8.** Schematic diagram of unmanned rolling.
6. Conclusion

This paper mainly introduces the application of intelligent unmanned paving and compaction system in pavement construction and introduces the application and effect of the system in engineering construction. In the actual process of asphalt pavement construction, it is found that on the premise that the mixture design fully meets the specification requirements and the indoor test evaluation also meets the requirements, there are great differences in the quality of asphalt pavement construction in different bid sections for the same highway with the same raw materials and mixture design method. This shows that due to the difference and fluctuation of highway construction levels, the uniformity of pavement quality is poor, resulting in serious segregation. It further shows that effective construction process quality control is an important factor in ensuring the quality of asphalt pavement. The emergence of intelligent construction is conducive to the control of important influencing factors in the construction process to a large extent, which is an important measure to improve the pavement construction quality and improve the construction control level. This intelligent construction technology realizes the real-time control of asphalt mixture paving and rolling and can timely feedback the construction status to the front-line operators and managers, effectively avoiding the blind area of construction key index control and ensuring the construction quality. Through the comparative analysis of application effects, the intelligent construction technology effectively reduces the fluctuation of key construction index data, improves the construction uniformity of asphalt pavement, and improves the construction quality.

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