Application of digital construction whole process monitoring and management technology for airport asphalt pavement

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Abstract. The construction and management of airport asphalt pavement project has the characteristics of large construction scale, high technology, many professionals involved, and high quality requirements. The traditional monitoring and management method that relies on manual on-site inspections and records is vulnerable to many factors such as environmental conditions and the ability of the implementer. It is difficult to ensure real-time monitoring of construction quality and data backtracking. With the rapid development of various advanced technologies such as global navigation satellite system(GNSS), geographic information system(GIS) and internet of things(IoT), digital construction monitoring and management technology for airport asphalt pavement has emerged as the times require. Digital construction technology is implemented through professional testing equipment, data collection, data integration, and system installation. It covers the entire construction process of airport asphalt pavement from the background management of the mixing plant, the transportation management of vehicles to the field management of paving and compaction. The technology monitors the construction quality, guarantees the construction progress, improves management efficiency, and saves costs, which has great social and economic benefits.

1. Introduction
The construction quality of the airport asphalt pavement is an important link related to the quality of the runway. The construction quality determines the service life of the overall project. The lack of a reliable quality assurance system will put huge pressure on the later operating costs [1,2]. The monitoring and management of asphalt pavement have always used the traditional manual recording method, which is easily affected by factors such as environmental conditions and the ability of the implementer. Construction information is fragmented, and it is difficult to ensure real-time, comprehensive monitoring and data backtracking of construction quality with the traditional method [3]. The current construction management methods have been unable to meet the needs of the rapid development of productivity. It is urgent to adopt a more scientific and efficient construction management plan, and to establish a more complete comprehensive quality management and process real-time monitoring system [4].

With the rapid development of various advanced technologies such as global navigation satellite system (GNSS), geographic information system(GIS) and internet of things(IoT), the airport has gradually formed all-weather, all-element, and all-round construction data acquisition conditions. In the face of multi-source and massive construction data and industry application requirements, the rapid
industrialization of digital construction has become an inevitable trend and requirement of the times [5,6]. This article introduces a digital construction system composed of professional testing equipment, data collection, data integration, and system installation and implementation. It covers the entire construction process from the background management of the mixing plant, the transportation management of vehicles to the field management of paving and compaction. The technology monitors the construction quality, guarantees the construction progress, improves management efficiency, and saves costs which has great social and economic benefits.

2. The technology mainly used in digital construction for airport asphalt pavement
In the digital construction process of asphalt pavement engineering, various technologies are organically combined to obtain more comprehensive and accurate construction information and ensure construction quality.

2.1. Global navigation satellite system (GNSS)
GNSS is a positioning system that uses radio signals loaded with special positioning information to achieve positioning measurements by continuously broadcasting specific frequencies to the ground [7]. GNSS usually includes three parts:

Satellite clusters operating in space. A constellation system composed of several satellites sends time signals, ranging signals and real-time coordinate position signals to the ground.

Ground control. By receiving the above signals, it is possible to accurately determine the satellite's orbital coordinates and clock difference, monitor whether its operation is normal, and insert new satellite orbital coordinates into the satellite to perform necessary satellite orbit correction and adjustment control.

The user part. It receives various signals sent by satellite broadcasting through the user's satellite signal receiver, and processes and calculates to determine the user's final location. The user receiver is usually fixed on a fixed target or vehicle on the ground for positioning and navigation.

Currently, the global satellite navigation and positioning systems in operation include the United States' Global Positioning System (GPS), China's Beidou Satellite Navigation System (BDS), EU's GALILEO and Russia's GLONASS [8].

2.2. Geographic information system (GIS)
GIS is a system for storing and managing spatial data. It also supports query, retrieval and analysis in the form of graphs and attribute data [9]. The use of GIS can intuitively and closely link various types of data and spatial locations during the airport construction stage, thereby promoting overlay analysis, obtaining comprehensive analysis results and visualizing airport information.

2.3. Internet of Things (IoT)
Internet of Things refers to a huge network formed by combining various smart sensors, radio frequency identification (RFID) devices, laser scanners and other devices with the Internet [10]. Various objects such as mixing plants, transport vehicles, paving vehicles and road rollers are all connected to the network, so that the system can automatically and real-time identify, locate, track, monitor and trigger corresponding events. The Internet of Things technology is of great significance to the characteristics of high mobility, long cycle and complex technology in airport construction and production activities.

3. Monitoring and management of the whole process of digital construction of asphalt pavement
Monitoring and management of the whole process of digital construction of asphalt pavement include background management of mixing plant, transportation management of vehicles and field management of paving and compaction. The overall technical architecture of the digital construction monitoring and management system adopts a distributed deployment method. Monitoring tools are installed on the equipment and the construction data is collected on the cloud server. After the data
processing in the cloud server is completed, it will be displayed on the GIS visualization software. The technical architecture is shown in figure 1.

Figure 1. The technical architecture of the digital construction system.

3.1. Background management of mixing plant
The production monitoring system of the mixing plant is a professional equipment for real-time collection of production data of the asphalt mixture based on the Internet of Things technology. It can monitor and collect the following production data: asphalt additive ratio, oil-stone ratio, feeding and discharging time, mixing plant output and productivity data. It realizes the digital monitoring of the whole production process of the asphalt mixing plant, especially in the aspects of gradation control, asphalt content control and temperature control.

3.1.1. On-site inspection of asphalt material.
In order to avoid the replacement of high-quality asphalt with inferior low-quality asphalt, spectral technology is used to develop an on-site inspection module for asphalt materials, which can quickly and accurately measure asphalt components at the mixing site. This realizes convenient and reliable asphalt raw material detection and guarantees the material quality of the asphalt mixture.

3.1.2. Quality monitoring of mixing facilities.
By installing a DLP data acquisition device on the mixing facility, the material volume, temperature and other information can be monitored in real time and accurately. Then the actual and accurate mix ratio data can be calculated, and the system will automatically alarm when the quality is found to be unqualified. At the same time, it can realize the statistical analysis of the production progress, the playback of the mixing process, the traceability of historical data, and the strict control of the production quality. The interface of the mixing process monitoring software is shown in figure 2.
3.2. **Transportation management of vehicles**

Based on radio frequency technology (RFID), RFID electronic tags and high-precision positioning systems are installed on each transport vehicle. The identifiers installed at the mixing station and the paver can record the transport vehicle information, identify the transport vehicle, and send it to the server of the monitoring software via the wireless module. This makes it possible to track the transportation route of each vehicle and monitor the entire process of the material from the mixing station to the paving, including the start and end time of the pick-up/discharge, the source batch and the corresponding paver number. And it also provides the corresponding data basis for the subsequent quality problem backtracking. When it is found that there is an out-of-range or long-term parking during the transportation, the alarm will be sent immediately by means of SMS, so as to quickly correct the transportation problem.

3.3. **Field management of paving and compaction**

As the most important construction equipment on site, pavers and rollers play a decisive role in the quality of the entire road construction. According to the characteristics of the paving and compaction process, various sensors and positioning systems are installed on the paver and roller to obtain the paving temperature, rolling temperature, rolling pass, paving/rolling level, and rolling speed, paving width, smoothness and other construction parameters. While achieving on-site machine group coordination through digital construction, the traditional quality inspection method is transformed from result inspection to digital process inspection. Rasterizing the construction site can not only replay the construction quality, but also know the quality of any construction location and whether it is excessive or omitted through the system.

3.3.1. **Paving construction quality management.**

Airport pavement construction materials are expensive, and the surface smoothness requirements are high, and it is one of the key factors for construction cost control and quality control. The application of intelligent paving positioning system in asphalt pavement can accurately control the slope, thickness and absolute elevation of each structural layer, eliminate the accumulation of errors, improve smoothness, and save materials and time.

3.3.2. **Rolling construction quality management.**

The rolling quality management system can accurately control the rolling trajectory, rolling temperature, number of rolling passes and other parameters of different types of rolling equipment (steel wheels, rubber wheels, etc.). The visual display of rolling effect is shown in figure 3. The characteristics of the system are as follows:
a. It adopts intelligent operating system, has wireless communication technology, and adopts precise measurement method for millimeter-level precision measurement. The system can be compatible with anti-segregation paving machinery with a paving width of not less than 12 meters.

b. The system can receive the 3D construction data of the paving construction from the BIM design file of the designer.

c. The system can obtain millimeter-level information of the spatial attitude of the paver screed through the real-time accurate measurement device. The system can collect the vibration frequency and moving speed of the paving screed and send the construction process data to the management software.

d. The system compares the spatial attitude information with the design file, and sends the comparison result to the system control unit. The system control unit drives the hydraulic cylinder to causes the vertical movement, which causes the slope and elevation of the filling to change to meet the design requirements of the paving construction.

e. The system can compare the construction unit information with the current construction information, and display and alarm if the actual construction does not conform to the construction standards.

4. Application example of digital construction quality monitoring technology in asphalt pavement

The west runway of the Capital International Airport was built in 1977, and asphalt concrete was overlaid in 2000. As of 2020, it has been in operation for 20 consecutive years, and the pavement has appeared wheel rutting, looseness and other diseases. It was urgent to carry out the construction of asphalt paving on the road surface. Nearly 500,000 square meters of paving area had applied digital construction quality monitoring technology. Digital construction quality monitoring equipment was installed on 2 asphalt mixing plants, 60 transport vehicles, 10 pavers and 24 rollers, and a digital construction monitoring visualization software was deployed. The condition of asphalt transportation vehicles, monitoring of paving and rolling quality could be obtained at all times. It guaranteed the paving quality of the asphalt pavement, controlled the construction progress, enabled the paving project to be completed ahead of schedule, and ensured the smooth navigation of the capital airport west runway in advance.
5. Conclusion
The application of digital construction technology has greatly improved the technical level of airport asphalt pavement construction, proposed new airport construction ideas and methods, and provided a good technical guarantee for modern airport construction. In view of the characteristics of airport pavement construction, such as long production cycles, complex coordination relationships, large impacts of natural conditions, complex engineering properties, and strict construction quality requirements, GNSS, GIS and Internet of Things technologies have been applied to all key aspects of airport runway construction. The most direct first-hand data obtained can be used by engineers and technicians to fully grasp the status of airport pavement construction from all angles. At the same time, digital construction improves the efficiency of construction management, saves costs, and brings great economic benefits.

Acknowledgments
This research was funded by the China Civil Aviation Safety Capacity Building Fund Project: Realization and Construction Demonstration of Digital Quality Monitoring System for the Construction of Gravel Pile in Airport Projects.

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