Construction Technology and Intelligent Decision-Making of Municipal Roads Under Complex Geological Conditions

Dongdong Sun

Suzhou Key Engineering Construction Management Bureau, Suzhou, Anhui, 234000, China

Keywords: Complex geological conditions; Municipal road construction; Construction technology; Intelligent decision-making; decision-making model

Abstract: This article focuses on the study of municipal road construction technology and intelligent decision-making under complex geological conditions. Under the background of accelerating urbanization, municipal roads often face complex geological conditions such as soft soil foundation and karst area. By analyzing the influence of complex geological conditions on construction, this study explores targeted construction technology and builds an intelligent decision-making system. Taking the municipal road construction project in a complex geological area of a city as an example, drainage consolidation method and grouting filling method are used to deal with special geology, and intelligent decision-making system is used to monitor key parameters such as settlement in real time. The results show that, for example, in the construction of soft soil foundation, the settlement is 50mm on the 30th day, 80mm on the 60th day and 100mm on the 90th day. After optimization, the average absolute error of the decision-making model decreased from 15mm to 8mm, the root mean square error decreased from 20mm to 12mm, and the decision coefficient increased from 0.80 to 0.92. The research shows that reasonable construction technology combined with intelligent decision-making can effectively deal with complex geological challenges and improve construction quality and efficiency.

1. Introduction

As a key component of urban infrastructure, the quality of municipal road engineering is closely related to urban development and residents' life. With the acceleration of urbanization, the geological conditions faced by municipal road construction are becoming more and more complex [1]. Complex geological conditions cover many types such as soft soil foundation, karst area, expansive soil area and landslide area, and these special geological conditions bring many difficulties and challenges to municipal road construction [2-3]. In the soft soil foundation area, the characteristics of high compressibility, low strength and high water content of soil are easy to cause road settlement and collapse, which poses a serious threat to the stability of road structure [4]. The phenomenon of karst caves and dissolved cracks in karst areas may lead to uneven settlement of foundation and even sudden collapse of pavement. The expansion and contraction characteristics of expansive soil will change with the change of environmental humidity, resulting in problems such as deformation and cracking of roads [5]. The stability of soil in landslide area is poor, and under the influence of rainfall, earthquake and other factors, it is easy to cause landslide disasters and destroy road facilities [6]. Faced with such complicated geological conditions, the traditional municipal road construction technology has been difficult to meet the needs of modern engineering construction. It is urgent to seek a more scientific, efficient and adaptable construction technology [7]. Futhermore, with the rapid development of information technology, intelligent decision-making has been widely used in various fields, providing a new development idea for municipal road construction.

With the help of advanced information technology, data analysis methods and intelligent algorithms, intelligent decision-making can collect and analyze all kinds of data in the process of municipal road construction under complex geological conditions in real time, and make scientific and reasonable decisions according to the analysis results [8]. It can not only improve the construction efficiency and ensure the construction quality, but also effectively reduce the

  DOI: 10.25236/icacel.2025.082

construction risk and improve the overall benefit of the project construction. Based on this, it is of great practical significance to study the construction technology and intelligent decision-making of municipal roads under complex geological conditions. By analyzing the influence of complex geological conditions on municipal road construction, exploring targeted construction technology and constructing intelligent decision-making system, it is helpful to promote the technical progress of municipal road construction industry and lay a solid foundation for the sustainable development of the city.

2. Construction technology of municipal road under complex geological conditions

Under complex geological conditions, municipal road construction technology needs to be selected and optimized according to different geological characteristics. For soft soil foundation, drainage consolidation method and composite foundation method are commonly used [9]. Drainage consolidation method accelerates the drainage of water in soft soil with the help of sand wells, plastic drainage plates and other facilities, so that the soil is gradually consolidated and the foundation strength is improved. The rule of composite foundation is to set piles in soft soil, such as cement mixing piles and CFG piles, to share the upper load with the soil between piles and enhance the bearing capacity of foundation.

In karst areas, the construction technology focuses on the treatment of karst phenomena such as caves. For smaller caves, grouting filling method is generally used to inject materials such as cement slurry into the caves to form stable structures. For larger caves, it may be necessary to use concrete to fill up and cross the structure to ensure the stability of road foundation [10]. In the construction of expansive soil area, the first task is to control the change of water content of expansive soil. The replacement method is often used to replace expansive soil with non-expansive materials, such as sand and gravel. Futhermore, a sealing layer will be set to prevent external moisture from infiltrating into the expansive soil and reduce the influence of soil expansion and contraction deformation on the road.

In the landslide area, the core of construction technology is to enhance the stability of soil. Retaining structures such as anti-slide piles and retaining walls can be used to resist the sliding force of soil. In addition, drainage treatment will be carried out to reduce the groundwater level, reduce the weight of soil and further improve the stability of landslide. The rational use of these construction techniques is the key to ensure the construction quality and safety of municipal roads under complex geological conditions.

3. Application of intelligent decision-making in municipal road construction

Data acquisition is the basis of intelligent decision-making. In the construction of municipal roads, multi-source data such as geology, topography and meteorology of the construction site are obtained in real time by means of sensor technology, satellite remote sensing technology and geographic information system (GIS). After preliminary sorting, the collected data will enter the data analysis link. Statistical methods are also used to calculate statistics such as the mean and variance of the data, and to evaluate the dispersion and stability of the data. Futhermore, the correlation analysis method is used to explore the correlation between different factors, such as the correlation between geological conditions and road settlement. Pearson correlation coefficient formula is:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

Among them, x_i and y_i are the i observation values of the two variables, $\bar{x}$ and $\bar{y}$ are the mean values of the two variables, and n is the number of observation values. By calculating

Pearson correlation coefficient r_{xy}, the linear correlation degree between geological factor x and road settlement factor y can be judged.

In the decision-making of municipal road construction under complex geological conditions, the commonly used algorithm models include neural network model and genetic algorithm. Neural network model can simulate the working mode of human brain neurons and has strong fitting ability for complex nonlinear relationships. Take Multilayer Perceptron (MLP) as an example, it learns the intrinsic pattern of data through the connection weights between neurons in input layer, hidden layer and output layer. Suppose there are n neurons in the input layer, m neurons in the hidden layer, k neurons in the output layer, the input vector is $x=(x_1,x_2,x_3,\ldots,x_n)$, and the output of the j neuron in the hidden layer is:

$$h_j = f\left(\sum_{i=1}^{n} \omega_{ij} x_i + b_j\right) \quad (2)$$

Where ω_{ij} is the connection weight between the i neuron in the input layer and the j neuron in the hidden layer, b_j is the bias of the j neuron in the hidden layer, and f is the activation function. The output of the l neuron in the output layer is:

$$y_l = f\left(\sum_{j=1}^{m} \upsilon_{jl} h_j + c_l\right) \quad (3)$$

Among them, υ_{jl} is the connection weight between the j th neuron in the hidden layer and the l th neuron in the output layer, and c_l is the bias of the l th neuron in the output layer. By constantly adjusting the weight and bias, the error between the output of the model and the actual value is minimized, thus realizing the prediction and optimization of the construction decision.

Genetic algorithm simulates the mechanism of heredity, mutation and selection in the process of biological evolution, and is used to solve complex optimization problems. In the decision-making of municipal road construction, the parameters of the construction scheme can be coded as chromosomes, and through genetic operations such as selection, crossover and mutation, a better construction scheme can be continuously generated. Intelligent decision-making provides scientific and efficient decision-making support for municipal road construction under complex geological conditions by building systems, collecting and analyzing data and applying appropriate algorithm models.

4. Case analysis and optimization strategy

4.1 Practical case analysis

In this study, a section of municipal road construction project is selected as the research case. The geological conditions in this area are complex, mainly soft soil foundation, with high groundwater level and small karst caves in some areas. In the early stage of construction, detailed geological data were obtained through geological exploration, such as the average thickness of soft soil layer is 8 meters, the groundwater level is about 2 meters from the ground, the distribution position and size of karst caves and other information. During the construction, the drainage consolidation method was adopted to treat the soft soil foundation, and the sand drain and plastic drainage board were used to accelerate the drainage consolidation of soft soil, and the grouting filling method was used to treat the karst cave. In the aspect of intelligent decision-making, an intelligent decision-making system including geological data, construction progress, material parameters and other multi-source data is constructed. Figure 1 shows the change of soft soil foundation settlement with time during construction.

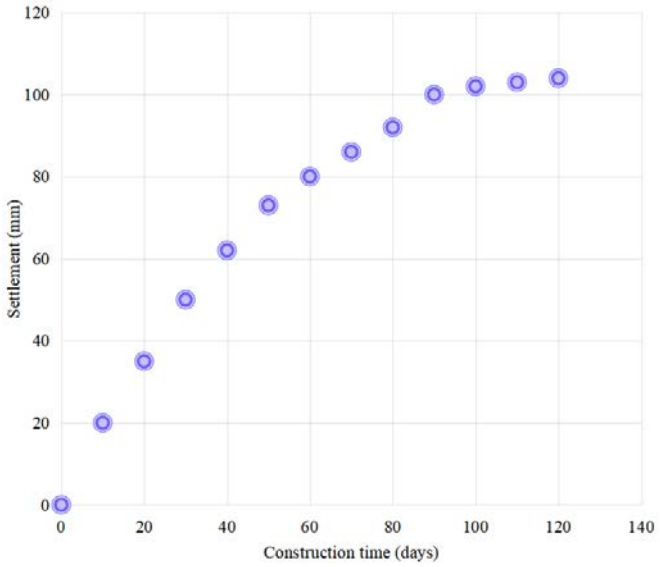

Figure 1 Variation of soft soil foundation settlement with construction time

At the initial stage of construction, the settlement increased rapidly, and with the progress of drainage consolidation, the settlement gradually stabilized. On the 30th day, the settlement reached 50mm, on the 60th day, it was 80mm, and on the 90th day, it was stable at about 100 mm. According to the real-time monitoring data, the intelligent decision-making system timely adjusted the rate of drainage consolidation and grouting quantity, effectively controlled the settlement of soft soil foundation and ensured the stability of road foundation.

4.2 Existing problems and challenges

Although the project has achieved some results with the help of intelligent decision-making, it still exposes some problems. First of all, in the data acquisition process, some sensors fail, resulting in the lack of data in some time periods, which affects the accuracy of decision-making. Secondly, the ability of the decision-making model to simulate the coupling effect of various factors under complex geological conditions needs to be improved. For example, in the area where soft soil foundation and karst cave coexist, the model fails to fully consider the effect of their interaction on road stability. Futhermore, intelligent decision-making system is facing the challenge of data security and privacy protection. Municipal road construction data involves urban infrastructure information, once leaked, it may bring serious consequences. In addition, the operators' proficiency and acceptance of the intelligent decision-making system are uneven, which affects the full play of the system functions.

4.3 Optimization strategies and suggestions

Aiming at the above problems, the following optimization strategies are put forward. In the aspect of data acquisition, the redundant configuration of sensors is increased, and the sensors are regularly maintained and calibrated to ensure the integrity and accuracy of data.

For the decision-making model, a more complex coupling analysis algorithm is introduced to deeply integrate geological conditions, construction technology, environmental factors and other factors. Table 1 shows the performance comparison of decision-making models before and after optimization in predicting road settlement.

Table 1 Performance Assessment of Decision-Making Models Before and After Optimization

Assessment Metric	Model Before Optimization	Model After Optimization
Mean Absolute Error (mm)	15	8
Root Mean Square Error (mm)	20	12
Coefficient of Determination (R^2)	0.80	0.92

The optimized model has significantly improved the average absolute error, root mean square error and other indicators, and the determination coefficient is closer to 1, indicating that the model has better fitting degree to the actual settlement and higher prediction accuracy.

In the aspect of data security, encryption technology is used to encrypt, store and transmit construction data, and a strict data access authority management system is established. In view of the operation problems of construction workers, the training of intelligent decision-making system is strengthened, and detailed operation manuals are formulated to improve the operation skills and cognition of construction workers to the system. Through these optimization strategies, it is expected to further improve the application effect of intelligent decision-making in municipal road construction under complex geological conditions.

5. Conclusions

In the construction, corresponding measures are taken according to different geological conditions: drainage consolidation and composite foundation method are used for soft soil foundation, grouting and concrete are used for plugging in karst area, replacement and sealing layer are used for expansive soil area, and anti-slide piles, retaining walls and drainage treatment are used for landslide area. Intelligent decision-making shows great advantages in municipal road construction. By constructing an intelligent decision-making system, the collection and analysis of multi-source data are realized, and the decision-making is made by using neural network model and genetic algorithm, which improves the scientificity and accuracy of construction decision-making. Based on the actual case, in the settlement control of soft soil foundation, the construction parameters are adjusted in real time with the help of intelligent decision-making system, so that the settlement is effectively controlled. However, during the construction process, problems such as data acquisition equipment failure, insufficient coupling simulation of complex factors in decision-making model, data security and personnel operation proficiency are also exposed. In the future, it is necessary to further optimize the sensor redundant configuration, introduce more complex coupling algorithms, strengthen data security management and strengthen personnel training. Generally speaking, the organic combination of municipal road construction technology and intelligent decision-making under complex geological conditions provides an effective way to improve the level of municipal road construction.

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