Study on monitoring simulation of urban space Environmental Science grouting by transient electromagnetic field

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Abstract. Grouting is one of the most effective methods to control underground space engineering disasters. It can effectively achieve a series of governance goals such as reinforcement of broken ground, reduction of settlement, and prevention and control of water and mud inrush. The form of the grouting process, the diversity of the grout, and the complexity of the stratum being injected are the key issues that restrict the development of grouting monitoring. Traditional grouting monitoring is mainly to control the grouting flow and pressure to achieve the grouting process and the state of grout diffusion. Routine testing The method can only perform spot inspection on the space or judge the overall space density, and it is difficult to monitor the spread of the slurry during the grouting process and the effective detection of the effect after the grouting. Based on the characteristics of transient electromagnetic sensitivity to low-resistance bodies, simple construction methods, and large detection depth, this paper uses theoretical analysis and numerical simulation as the main research methods to carry out forward simulation research on the diffusion process of grout in the formation. Through the establishment of numerical models for the different content of slurry in the middle layer of the same thickness layered formation, the possibility of using the electromagnetic field to explain the slurry diffusion in the grouting process is explored. Under ideal conditions, the transient electromagnetic response characteristics of the middle layer with different slurry conditions are analyzed. It is proved that the change of the field value of the transient electromagnetic secondary field before and after grouting can effectively judge the intrusion effect of the grout during the grouting process.

1. Introduction
With the process of urbanization in China, a large number of people have poured into cities. Some problems are beginning to be exposed in the process of urbanization. The first problem is that the urban space is greatly insufficient. For this reason, the city began to expand to surrounding areas and underground. In order to carry out efficient and safe underground space development, accurate engineering quality evaluation is the key to ensuring safe operation [1]. The construction and maintenance of underground space involve all aspects. The detection of underground space is a key part, which plays a decisive role in the evaluation of the effect of underground engineering construction. The two geological difficult strata involved in underground engineering construction include high pressure and rich water and weak stratum. Solving these two situations in the process of underground engineering construction has become an urgent problem to be solved. Grouting technology can be used as an effective means to strengthen the ground, and how to effectively check the grouting effect has become a difficult problem.
Geophysical methods play a very important role in the engineering inspection of construction projects. As a kind of geophysical method, the transient electromagnetic method has the characteristics of green, environmental protection, and high resolution for underground media. The transient electromagnetic method uses ground transmitter coils or long wires to supply power to the underground. When the current is turned off, electromagnetic induction acts. The generated space magnetic field will stimulate the underground medium body to generate signals, and the electromagnetic field signals are collected by artificial or unmanned aerial vehicle coils to achieve the goal of exploring underground abnormal bodies. The transient electromagnetic method has the advantages of being sensitive to low-resistance objects, having strong strength close to the target, and convenient in construction. It has been widely used in the fields of advanced detection of roadway excavation and detection of water-rich areas on working faces. Carrying out the simulation research of the transient electromagnetic method in the grouting process can not only guide the data interpretation in actual work, improve the interpretation accuracy, but also lay the foundation for the three-dimensional evaluation of the grouting engineering effect that is still in the research stage. Important promotion effect [2].

2. Materials and Methods

2.1. Introduction to the method of grouting engineering

Grouting technology plays an irreplaceable and important role in civil engineering, water conservancy, transportation, mining, and other engineering fields. It mainly includes the reinforcement of building foundations and settlement prevention, anti-leakage treatment and reinforcement of poor geological bodies of dam foundations, subway and Grouting reinforcement in water-rich tunnels, treatment of roadbeds of highways and railways, and airport runways, such as vacant collapse and grouting reinforcement, slope support and grouting reinforcement in anchorage areas during foundation pit excavation, to ensure the effectiveness of cast-in-place piles. Post grouting for bearing capacity and repair and reinforcement of cracks in cultural relics and historic sites [3-4].

![Grouting process](image)

**Figure 1. Schematic diagram of grouting process**

2.1.1. Grouting process

With the application of grouting technology in municipal engineering, road and bridge engineering, mining engineering, and other fields, the technology continues to develop and progress, and the grouting technology is constantly evolving. The current main construction technology is ① the drill pipe grouting method, which uses grouting. After the drill pipe is drilled to the specified depth from the borehole, the grouting material is sent into the formation through the inner tube; ② The single filter tube grouting method is to set the filter tube in the drilled formation first, and use sand, The gap between the pipe and
the formation injects the grout into the target layer; ③ The double-layer pipe double-plug grouting method is to set plugs in two places in the grouting pipe to make the grout seep out from the middle of the plug to the outside of the pipe; In the layered pipe drill pipe grouting method, the double-layer drilling tool including the drill bit is driven to the target layer, and the double-liquid synchronous grouting pump is used to inject the double-liquid into the formation.

2.1.2. Grouting material
Grouting material is the core of grouting technology, and its development has promoted the innovation of grouting technology. At present, two major systems have been formed in the field of grouting materials, namely the true solution type chemical grouting material system represented by organic polymer materials such as polyurethane and epoxy resin, and the inorganic particle type injection system represented by cement and clay. Pulp material system [5]. In recent years, some environmentally-friendly grouting materials have become popular, mainly relying on modern technology to screen, process, process, equip, and apply solid waste such as tailings to increase the value of solid waste while reducing the environmental pollution. At the same time, the development and progress of biological and chemical technologies have promoted the mass development and engineering application of new grouting materials [6].

2.1.3. Grouting inspection
The detection of the grouting effect is the basis for evaluating the results of grouting. At present, the detection of grouting engineering effects is mainly divided into four categories: ① Analytical methods, including PQt curve method, inverse grout filling rate algorithm, grouting volume distribution characteristic method, Four kinds of water inflow comparison methods; ② Drilling inspection method, including inspection hole observation method, inspection hole core method, inspection hole PQt curve method, inspection hole PQt curve method, etc.; ③ Excavation sampling method, including reinforcement effect Observation method, grouting mechanism analysis method, mechanical index testing method, deformation estimation method, etc.; ④ Geophysical methods, including borehole acoustic wave method, borehole imaging method, seismic wave method, geological radar method, etc.

2.2. Introduction to the transient electromagnetic method
Forward simulation is the basis of inversion calculations. Improving the calculation efficiency and accuracy of forwarding simulation is a necessary condition for fast and stable completion of three-dimensional inversion [7]. It is of great significance for realizing effective monitoring of changes in electromagnetic properties of underground space. A reliable method for effective three-dimensional evaluation of effects. Maxwell's equations are the basic equations that reveal the law of electromagnetic wave propagation. Starting from Maxwell's equations, obtaining the law of electromagnetic field propagation is the research focus of the geophysical electromagnetic method [8]. For a complex three-dimensional geoelectric model, it is difficult to analyze the Maxwell equations to simulate the propagation law of electromagnetic field, and numerical calculation methods can solve this type of problem.

3. Results & Discussion
In this paper, the transient electromagnetic method is applied to the effect inspection and evaluation of the grouting engineering technology through simulation, and the corresponding characteristics of the transient electromagnetic field in the grouting process are used as a means to test the spread of the grout, to judge the effect of the engineering grouting. Three models are set up to simulate the changes in resistivity of the underground formation before, during, and after the grouting process (corresponding to A, B, C in Figure 2). The formation model in Figure 2A: \( \rho_1 = 1000 \Omega \text{m}, h_1 = 20\text{m}, \rho_2 = 500\Omega \text{m}, h_2 = 20\text{m}, \rho_3 = 10000\Omega \text{m}; \) The formation model in Figure 2B: \( \rho_1 = 1000\Omega \text{m}, h_1 = 20\text{m}, \rho_2 = 500\Omega \text{m} (\rho \text{ slurry} = 10\Omega \text{m}), h_2 = 20\text{m}, \rho_3 = 10000\Omega \text{m}; \) the formation model in Figure 2C: \( \rho_1 = 1000\Omega \text{m}, h_1 = 20\text{m}, \rho_2 = 10\Omega \text{m}, h_2 = 20\text{m}, \rho_3 = 10000\Omega \text{m}. \) The forward simulation of grouting is shown in Figure 3. It can
be seen that the effect of grouting can be judged by observing the change of the field value of the secondary field of the transient electromagnetic method before and after grouting. The results show that this method can effectively judge the effect of grout invasion in the grouting process.

4. Conclusions
(1) The time-frequency signal of the transient electromagnetic method can well reflect the distribution of the grout filling in the underground space during the grouting process, and can be used as an effective means of monitoring and effect detection of the grouting engineering process; (2) the transient electromagnetic method reflects the situation of the secondary field excited by the underground medium after electromagnetic induction. When used for the monitoring of the grouting process, the magnetic component can be added to the grout material to increase the dielectric difference between it and the surrounding rock, which is beneficial to more effective Monitoring and testing of grouting; (3) Monitoring the grouting process is conducive to engineering control, saving costs and reducing consumables, and evaluating the grouting effect is conducive to ensuring project quality and safety. To sum up, the monitoring and testing of grouting engineering through transient electromagnetic method has good social and economic benefits, and it is worthy of in-depth study and promotion.

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