Seismic Exploration of the River Sand Mining Area

Jian Zhang¹,a, Lei Fang¹,*, Yanhai Wang²,b, Jun Mei³,c

¹School of Geotechnical Engineering, Southeast University, Nanjing, China
²Transportation Planning and Design Institute of Xuzhou, Xuzhou, China
³Environmental Geology Exploration Institute of Jiangsu Province, Nanjing, China

*Corresponding author e-mail: 1345220562@qq.com, a1554359311@qq.com, bxzjtsjy@163.com, c382920961@qq.com

Abstract. Engineering geophysical exploration plays an important role in the geotechnical field. It is based on the difference in physical properties of rock, ore (or stratum) and surrounding rock, magnetization, conductivity, and radioactivity, and thus the distribution of various physical fields on the earth. Observations of changes and their changes are currently used in shallow seismic exploration and transient electromagnetic surveys. Based on the exploration demand of a river sand mining area, this paper studies the shallow seismic exploration method and transient electromagnetic method which can carry out geophysical exploration in the sand mining area, and analyse its conditions of using, mechanism principle, results analysis and reliable detection. The difference between the two is that the two have their own advantages and disadvantages. However, for the exploration requirements of the river sand mining area, the shallow seismic exploration has the advantages of lower cost, simpler operation and stronger anti-interference ability. Through actual operation, shallow seismic exploration not only detects the specific collapse area of the sand mining area, but also detects the influence range and depth of sand mining, and provides a data basis for site stability evaluation.

1. Introduction

Engineering geophysical exploration is the abbreviation of engineering geophysical exploration. It is based on the difference in physical properties of underground geotechnical layers (or geological bodies), and the extent of spatial distribution (size, shape, depth, etc.) of underground geological bodies is determined by instrumental observation of changes in natural or artificial physical fields. The physical parameters of the rock mass reach a physical exploration method to solve the geological problem [1]. The main advantage is that it breaks the limitation of traditional drilling on construction conditions, especially in the offshore areas of rivers, which reduces the difficulty of construction. Secondly, compared with the traditional sampling of sampling difficulties and sampling disturbances, engineering geophysical methods use more inversion of measurement data to reduce errors. Finally, geophysical techniques directly process and analyze data after collecting data, with fewer link and faster. This paper will compare two widely used geophysical methods and conduct geophysical exploration in the sand mining area.
2. Engineering geological conditions

2.1. Project Overview
The upper structure of a bridge in a sand mining area is a prestressed concrete composite box girder with a corrugated steel web and a prestressed concrete box girder. The lower part adopts a pile foundation. Geophysical techniques were used to detect the conditions of the sand mining area.

2.2. Regional geological conditions
The landform unit belongs to the alluvial plain area, and the site is mostly farmland, river course and fish pond. According to the geological data revealed by the site survey, the rock and soil body is divided into 13 layers according to the differences in their genesis, age and physical and mechanical properties (A total of 26 sub-layers, the soil layer of the sand mining area is disturbed, the soil layer number is the number of the soil layer before the disturbance, and the letter C is added) after disturbing the soil layer number. The 1st to 4th layers are the Quaternary Holocene (Q4) sediments, the 5th to 11th layers are the Quaternary Upper Pleistocene (Q3) sediments, and The 12th to 13th layers are the Quaternary Pleistocene (Q2) sediments. Geological drilling data indicates that the Quaternary coverings in the area are mainly composed of silt, silty clay, medium coarse sand and coarse sand.

3. Detection method selection
The purpose of geophysical exploration is to find out the distribution range and depth of impact of the sand mining area based on the preliminary survey results, and initially evaluate the site stability of the bridge site to provide a basis for the preliminary design of the bridge. Both shallow seismic exploration and transient electromagnetic methods can meet the requirements. The principle, operation, detection reliability, and data processing are compared below.

3.1. Principle analysis

3.1.1. Shallow seismic exploration. After the underwater sand mining area is mined, it will inevitably cause its subsidence area at the bottom of the water. The sand body of this part of the formation is missing, forming a contrast with the surrounding sand layer, and the wave impedance (the density \( \rho \) of each medium and the wave in the medium) The product of the longitudinal wave velocity \( V \) of the propagation, called the wave impedance or the acoustic impedance, has a large difference, so there are different wave impedance interfaces. When the artificial source emits the seismic longitudinal wave, the water surface receiving instrument can be based on the time when the reflected wave is reflected back. And intensity for depth judgment.

When the seismic wave is reflected and transmitted in the interface of the medium with different wave impedances at the interface between the elastic solid and the saturated sandstone \([2,3,4]\), the energy is redistributed, especially when the seismic wave is perpendicularly incident on the interface of the medium with different wave impedance. Continue to propagate forward through the interface, called the transmitted wave; and the other part is reflected back, called the reflected wave. Since there is no vibration component along the interface direction at normal incidence, the incident wave, the reflected wave, and the transmitted wave propagate along the normal direction of the interface. The amplitude of the incident wave is \( A_i \), the amplitude of the reflected wave is \( A_r \), and the ratio of the reflected wave to the amplitude of the incident wave is called the reflection coefficient \( R \) of the reflective interface. When the wave is incident perpendicularly to the interface, \( R \) is as follows:

\[
R = \frac{A_r}{A_i} = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1}
\]

In multilayer media, the reflection coefficient is as follows:
It can be seen from the reflection coefficient that when \( R = 0 \), there is no interface, and no reflection of waves occurs. A reflected wave can be formed only when the reflection coefficient is not zero. The greater the difference in wave impedance, the larger the \( R \), the stronger the reflected wave. The range of \( R \) is -1 to 1. When \( R > 0 \), the reflected wave and the incident wave have the same phase, and both are positive; when \( R < 0 \), the reflected wave is negative, which is opposite to the incident wave and is 180 degrees out of phase. This phenomenon is called “half wave loss”. It is shown that reflection occurs only when there is a wave impedance interface. At the same time, different reflection coefficients can be determined when the wave impedances are different, and the observed reflected wave intensities are also different.

When longitudinal wave observation is carried out in the sand mining area, there is a different wave impedance at the interface between the subsidence area and the sand body caused by the sand mining area, which forms a wave impedance interface, and the difference in wave impedance between the sand body and the ground in the deeper part is another wave impedance interface, and the reflection coefficients of the two are different. Among them, the density of the foundation is the largest, followed by the sand layer. The received reflected wave intensity is also different. When the depth of influence of the survey area is all located in the sand layer, two reflected waves with a certain time difference should be measured, and their phases are opposite. The product of the time difference and the wave is the depth of influence. When the depth of the survey area is deep and deep below the sand layer, two reflection waves with a certain time difference should be measured, and their phases are opposite. The product of the time difference and the wave is the depth of influence. In comparison, when the depth of influence of the survey area has been deep below the sand layer, the second reflected wave is stronger.

3.1.2. Transient electromagnetic method. It is a method of using a non-grounded return line or a grounding wire source to send a pulsed magnetic field to the ground, and using a coil or a grounding electrode to observe the secondary eddy current field during the interval of one pulsed magnetic field [5, 6]. The river sand mining area can be divided into water layer, sand layer, goaf and underground rock mass in a certain section. The rock layers in each layer are different in electrical properties, and the generated magnetic fields are different. Therefore, according to the signals received by the recovery device and the post-processing analysis, the situation of the sand mining area can be basically understood.

The basis of transient electromagnetic detection is mainly to receive the induced voltage \( V(t) \) observed by the coil, and its relationship with the applied magnetic field is as follows:

\[
V(t) = -\frac{d\Phi}{dt} = -q \frac{ds(t)}{dt} = -SrN \frac{ds(t)}{dt}
\]

In the formula: \( \Phi \) is the magnetic flux cut by the receiving coil; \( q \), \( Sr \) and \( N \) are the effective area, area and the number of turns of the receiving coil respectively.

The magnetic induction can be calculated from the induced voltage:

\[
B(t) = \int_t^\infty \left[ V(t) / q \right] dt
\]

When detecting in the river sand mining area, the river can be divided into water layer, sand layer, goaf (influence depth) and underground rock body from top to bottom. Different formations have different resistivities. When the magnetic field generated by the primary current passes through
different formations, secondary current is generated. When the secondary current propagates in
different formations, the current consumption caused by the different resistivities is different. The
resulting secondary magnetic field has a difference in intensity. The secondary magnetic field received
by the receiver on the water surface has a difference in strength. Based on this difference, a geological
section can be drawn to understand the distribution range of the underground sand mining area. The
determination of the depth of influence of the sand mining area requires the calculation of the time
difference of the acceptance of the electromagnetic field in the upper and lower areas of the goaf.

3.2. Data Processing Analysis
The transient electromagnetic method is derived from electrical exploration, and its high-precision
transient electromagnetic system has achieved great results since its development. In the actual
application of the project, the effect is obvious. In the shallow exploration, it has the advantages of
high precision, low resistance, sensitive instrument, light instrument, fast data collection and low cost.
In recent years, it has been involved in water exploration, and it is more targeted to the detection of
goaf in underground space.

Shallow seismic exploration is widely used in rivers and shallow sea areas. The main advantages
are relatively simple operation, low cost, certain detection accuracy and strong environmental
adaptability. It can be said that it is an effective engineering geophysical method, which can directly
reflect the distribution of the bottom stratum and bedrock of the river and its fluctuations. The
exploration results can make up for the shortcomings of geological drilling methods. Combined with
the drilling results, the interface between the river water and the cover layer, between the various
cover layers and between the cover layer and the bedrock can be effectively divided, which not only
improves the accuracy of engineering survey, but also effectively improves the accuracy. The
efficiency of engineering survey has broad application prospects in river and marine engineering
surveys.

3.3. Reliability Analysis
The results of shallow seismic exploration in the river sand mining area can basically meet the
requirements, and the factors affecting reliability are mainly two points, one is the collection of signals;
the second is the processing of signals. When the signal is collected, the reflected wave formed by the
transmitted longitudinal wave has the problems of weak signal and absorption of the formation, which
affects the work of the receiving instrument. In this paper, the ground layer is simple and easy to
identify and the reliability is improved. When the signal is processed, the original data generally has
useless or interference data, half of which originates from the interference of water flow and motor
boat, and half of it originates from the abnormal signal collected during detection. The former can be
eliminated by high-pass filtering method, while the latter need to be eliminated based on the
consistency and rationality of the data [7].

Transient electromagnetic method has better prospects than traditional electric exploration, and has
obvious advantages in water exploration. The effect on the high resistance shield can be overcome. In
places where hard ground, cement floor, etc. are difficult to ground and the DC method cannot be used,
the transient electromagnetic method can still achieve good detection results. The influence factor of
its reliability is mainly the shielding effect of the water-rich and low-resistance layer [8,9].

3.4. Advantage comparison
In summary, firstly, transient electromagnetic method in shallow seismic exploration and electrical
exploration in seismic exploration can meet the requirements of geophysical exploration in river sand
mining area; secondly, Second: shallow seismic exploration has a wider application range and lower
cost. It is used in shallow sea areas and in land exploration. The disadvantage is that the operation is
cumbersome and requires pre-arrangement of cables; thirdly, the transient electromagnetic method is
better in the stratified river sand mining area, with better precision and flexibility, but the power boat
can’t be used to cause a small detection rate, and there is no obstacle blocking construction when towing. Lead to certain restrictions.

However, considering the situation on the spot, there is a breeding area on the river. The water tank in the culture area has a great interference to the implementation of the transient electromagnetic method. At the same time, the busy rivers around the river will cause electromagnetic interference, and there may be floating low-resistance layers below the sand layer, so shallow seismic exploration is selected.

4. Seismic exploration and analysis of results

4.1. Technical parameters

Considering the geological conditions of the Bridge, the shallow seismic exploration equipment selects the US Geode digital seismograph, and uses the floating floating cable for signal reception. The GPS performs the fixed point of the measuring point, setting the main frequency 60-80Hz, the track distance is 2m or 4m, 24 channels. The specific technical parameters are shown in Table 1 below.

| content                      | Technical Parameters                  |
|------------------------------|--------------------------------------|
| Observing system             | Unilateral excitation, single-sided reception and drag-and-drop |
| Offset                       | 0-1m                                 |
| Record length                | 0.5s                                 |
| Number of coverage           | 4-6                                  |
| Cable sinking depth          | 1.5m                                 |
| Source water depth           | 1.5m                                 |

4.2. Data Processing

Firstly, based on the measured track map, effective gun record selection is performed to ensure the number of times of coverage, and the serial number of the cannon record file is re-arranged, and then the seismic data is processed. After the spectrum analysis → frequency filtering → speed scanning → motion correction superposition, etc., the preliminary reflection seismic time profile is formed, which is mainly used for field quality monitoring. Finally, post-processing includes predictive deconvolution, residual static correction, multiple velocity analysis, time-dissection migration, de-noising and other special treatments to achieve the purpose of highlighting effective waves and suppressing interference waves, and forming a reflection seismic time profile after processing. Finally, according to the tide level data, the tidal level correction of the time profile is used as a result interpretation. The following figure shows the local time profile and the seismic data processing flow chart.

![Figure 1. Sectional view of shallow earthquake time in the sand mining area of the local survey line.](image-url)
4.3. Analysis of results
Through the processing of shallow geological exploration data, the detection depth of the sand mining area has obtained accurate figures, and the depth of influence is mostly between 30m and 50m. When evaluating the stability of the site, the site is temporarily unstable according to the data. But it will tend to be stable. The preliminary exploration targets have been basically completed.

5. Conclusion
This paper studies the geophysical methods of river sand mining area, analyzes the principle of geophysical methods, and combines practical cases to draw the following conclusions. Firstly: the existing geophysical techniques are sufficient to meet the detection requirements of the river sand mining area, but the appropriate geophysical methods should be selected. Secondly, From the applicability analysis of geophysical exploration, the transient electromagnetic exploration in shallow seismic exploration and electric exploration in seismic exploration can basically meet the requirements of geophysical exploration in river sand mining area, and the prospect of transient electromagnetic method is broader, while shallow layer Seismic exploration technology is more mature. Thirdly, According to the geophysical practice of the Jinghang Bridge in Pizhou, shallow seismic exploration is practical and operable.

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