The Application of Integrated Geophysical Method in the Detection of Ground Subsidence Area

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Abstract. In the detection of a subsidence area, in order to accurately determine whether there are holes in the backfill area, the CSAMT and the transient electromagnetic method shall be selected for integrated detection based on the geological and field conditions, and the analysis results show that the two methods of detecting results are basically identical by analyzing the abnormal characteristics of the typical sectional profile, but each has its own characteristics: The depth of CSAMT method is deeper than TEM, and the judgment of the abnormal area is relatively accurate, the resolution of TEM is better than CSAMT, but the detection depth is shallow, the depth of exploration is easily affected by the physical properties of the medium within the target depth and the shallow has a blind area. By drilling through the abnormal areas of the judgement, the results show that the detection results are accurate, and that the integrated geophysical method is accurate and effective in the collapse of backfill area.

1. Introduction
In August 2016, the central province of a road on the north side of the farmland ground subsidence occurred, the collapse area of about 70 square meters, after the incident, the relevant departments organized a professional team, the collapse sections of backfill grouting, the field survey data of normal professional sector. In November 2016, there were second collapses at the original collapse of the section, 26 meters wide in the subsidence area, 30 meters in the north and south, and 10 meters in depth. The subsidence area expanded to the road surface, causing two cars on the road to fall into craters, but no casualties were found. After the relevant units of the two times of backfill collapse pit, and carry out continuous subsidence monitoring in the backfill after the end, in order to avoid re collapse, geological conditions need on subsidence below and collapse pit backfill detection, to ensure the foundation and backfill strong and dense, and restore road traffic as soon as possible, reduce the loss.

Figure 1 Scene of ground subsidence.
The author uses the comprehensive geophysical detection of subsidence area, the main task is to carry on nondestructive detection of subsidence area is about 50m long and 30m in width, to identify the range of 0~165m settlement pit collapse area backfill sediment hole in the distribution occurrence, the detection results showed the presence of low resistivity anomaly area subsidence pit, after verified by drilling then, with the comprehensive analysis of engineering geological data, the area has been found in the cavity and imperfect collapse, through continuous monitoring and settlement of more than a year of restoration, road traffic has been restored. This paper mainly introduces the application effect of controlled source audio magnetotelluric (CSAMT) and transient electromagnetic method in this project.

2. General situation of engineering geology
After investigation, the district seat for an iron ore mining area collapse, the 165m below the ground for old iron ore mining area on the ground, two comprehensive measures have been taken before the collapse of underground filling and surface exploration borehole filling combination, multilateral verification, underground goaf backfilling have been determined, two non underground mining subsidence goaf collapse. The lithology around the subsidence area is mainly Cambrian, Ordovician, Carboniferous, two fold rock and Quaternary overburden. The Ordovician is the main ore-forming surrounding rock in the iron ore area, and mainly consists of diorite porphyry and quartz diorite porphyry.

Besides, the vicinity of the collapse area is adjacent to a large freshwater lake with a high groundwater level. The detection area is located around the town, surrounded by houses and lots of high voltage lines. The terrain conditions in the survey area are uneven, half of them are located on the highway, half of the farmland, and the terrain is generally flat.

3. Detection method
There are some common methods of engineering geophysical artificial seismic method, electrical and electromagnetic methods, the detection depth and the main method of artificial earthquake ground excitation source and continuous measurement of cloth line length, the greater the excitation energy, continuous ground line length, depth increases, and the detection area in urban fringe the houses around, with larger energy source of life impact on nearby residents is larger, and line detection area around not continuous arrangement of long length[1-2].

Because the target depth of more than 165m, and the detection area is located in the edge of town, the common method such as high density resistivity method and MT sounding method, the detection depth limitations and poor anti-interference ability, in the detection also should not be used[3-8]. Based on the above analysis, according to the actual situation and exploration experience, previous site reconnaissance this time, the instantaneous detection to detect the target area of transient electromagnetic method and controlled source audio MT method, the transient electromagnetic method using nanometer transient electromagnetic acquisition device to improve the detection accuracy of the shallow depth of 0~40m, the main area of the equipment is GDP-32II instant produced in the United States. The CSAMT mainly detects the area of -40~165m. The selected instrument is the V6 type controlled source audio MT instrument produced by the Phoenix company of Canada.

4. Line layout
The target area detection for rectangle 50m * 30m, the target area is 1500m², the target area is located near the F2 fault, scene detection, according to the site topography, geological data and detecting effect, arranged in 8 lines, similar to the fault direction orthogonal, the subsidence area full coverage, line the spacing is 5m. The layout of the test line is shown in Figure 2.
Anti interference measures: the measurement area is above the high voltage transmission line, through the field test, found that the high voltage transmission line effects on test data is large, to ensure the quality of the data and the detection effect, time varying electromagnetic field data acquisition in CSAMT and TEM, take measures against interference power transmission lines. In addition, the field data acquisition, in both electrode and station with red marker, and with a thick layer of clay and brine solution to the difficulty of grounding electrode conditions.

5. Detection results
Through the data processing, calculation and analysis of CSAMT and transient electromagnetic method, the resistivity profile of each line is obtained. According to the characteristics of the two detection methods, the limitation of the surrounding environment and the actual situation of the detection effect, the CSAMT method is the main method for the comprehensive detection, while the transient electromagnetic method is the secondary one. In the process of data processing, the boundary conditions of different detection methods are not exactly the same, and the two methods are different from each other, which leads to the inconsistent results of the two methods on the same line. In the interpretation of the data, we should combine the characteristics of the two methods and refer to the geological data and the previous experience of detection, and make a comprehensive analysis of the results[1-2].

In addition, according to the survey, site conditions of the existing geological data and drilling near the collapse area on the north side of the fault of F2 comprehensive analysis, survey area is located near the lake, the underground water level is higher. The subsidence area surrounding the borehole data found (alteration) granite diorite porphyry, alteration in kaolin, rock powder is mud or silt, part of drilling in the rock also found water phenomenon, the possibility that F2 fault of water in the larger, so that the possibility of not filling hole filled with water the larger, if the cavity is filled with water, in general in the show for the low resistivity zone.
Therefore, in order to identify the cavity area, the emphasis of the data interpretation is placed on the low resistance anomaly. Figures 3 and 4 are examples of detection results of line 3 and line 5. The left side is a CSAMT section on the left, and the right is a transient electromagnetic section. Comprehensive analysis of 7 lines of the visible, effective detection depth method of CSAMT remained at 200~250m, and the effective detection of transient electromagnetic method in 60~120m, which measured the detection depth line 1 to line 5 to 100~140m, and the detection depth line 6~ 8 50~75m, CSAMT overall the detection depth deeper than the transient electromagnetic method, and different line due to the formation of different geological conditions, large depth difference.

According to the CSAMT profile of the line 3 shown in Figure 3, a low resistance strip is found between the 3 pile number 1.5~4.5m of the survey line and extends deep to the depth of 200m. It is presumed that the fault is related to the geological structure. It may be caused by the fault zone. Besides, it is located between the 3 pile number 16~22m of the survey line, and has a low resistance area. The depth lies between 45 and 70m.

According to the Figure 4 line 5 CSAMT profile, in the line between the 5 pile No. 45~60m is perpendicular to the low resistivity zone, to extend the depth of 150m, the resistivity value is less than 100 m, and the 27J-27K section of the resistivity greater than 200 ohm arranged m, horizontal distribution for m obvious discontinuity. According to this, it is inferred that the fault zone passes through. In addition, it is located between the 5 pile number 45~60m of the survey line and the depth between 30 and 70m, which is a low resistivity anomaly area. It is presumed to be related to clay or groundwater.

Comprehensive analysis of Figure 2 and Figure 3 shows that the two kinds of detection methods in the same line at local areas were found in the low resistivity, and the position in the level and the depth of the anomaly area are basically the same with the other 6 lines. According to the analysis of two kinds of geophysical exploration methods results in target detection, high resistivity zone depth found in the apparent resistivity value is not high, and there are differences in the high resistance region without filling hole formation. It is inferred that this anomaly may be related to clay filling or groundwater.
The position of the low resistivity anomaly area in the resistivity section of each line is distributed on the plane, and the low resistivity anomaly distribution diagram, as shown in Figure 5, is obtained. It is numbered I, II, and III. It can be seen that the low resistivity anomaly area is mainly distributed in the East and west regions of the measured area. According to the drilling data of the different depth of each borehole collapse area surrounding the were found in the granite diorite porphyry, lithology description has "kaolin" and "rock powder is like mud, mud and described that change in the groundwater level, the permeable stratum with high moisture content, high probability. In addition, combined with the analysis of geological data in this area, it is presumed that the location may be located around the F2 fault. Due to the influence of faults, the geological differences of different parts are quite different.

In conclusion, according to the results of two kinds of geophysical methods in the area of subsidence, it shows that within the depth of 0~165m, the strata are densely packed, but the low resistivity anomaly areas are found locally. The abnormal areas are mainly distributed around the settlement pits. The cause of formation of low resistivity anomalies are various, including water clay, water filling holes and artificial filling, in order to accurately determine the causes of low resistivity anomaly detection results, through the core to determine the physical line profile in typical low resistivity zone, to determine whether because of the air hole filling water.

6. Result verification
In order to find out the cause of the low resistance anomaly and exclude possible water filling and muddy filling voids in the low resistivity area, we will select typical low resistivity regions from the survey results to verify core drilling. The other area is located near the F2 fault detection due to differences in different parts of the geological strata, large, comprehensive analysis of the above information, determine the arrangement of four 01 02, which verified drilling, and 03 holes are low resistivity anomaly verification holes, YZK04 high resistivity anomaly verification hole, hole layout shown in Figure 6.

| Hole number | Measuring line-pile number | Final hole depth | Quaternary thickness (m) | Core length (m) | Rate of adoption (%) | Bedrock thickness (m) | Core length (m) | Rate of adoption (%) | Cement quantity | Grouting quantity | Pulverized coal quantity |
|-------------|---------------------------|-----------------|--------------------------|-----------------|----------------------|---------------------|-----------------|----------------------|-----------------|----------------|-------------------|
| YZK01       | Line 8-55m                | 85.14           | 12.4                     | 4.5             | 36.3                 | 80.64               | 52.6            | 65.2                 | 65              | 172.425         | 49.29             |
| YZK02       | Line 8-10m                | 40.06           | 12.69                    | 6.5             | 51.2                 | 27.37               | 22.3            | 81.5                 | 0               | 3470.481        | 225.15            |
| YZK03       | Line 3-19m                | 130.97          | 109.3                    | 82.15           | 75.2                 | 21.67               | 17.4            | 80.3                 | 3470.481        | 225.15          |                   |
| YZK04       | Line 7-46m                | 120.35          | 14.47                    | -               | -                    | 105.88              | 83.9            | 79.2                 | 132.354         | 12.6            |                   |
It is indicated that no abnormal void was found in the area of verification which no drilling phenomenon occurred during the 4 verifying drilling processes according to the results of drilling. The results of geophysical and borehole histogram are compared and analyzed. The results are shown in Table 1, and the results are as follows:

The depth of YZK01 hole transient electromagnetic profile shown in Figure 7 is 25m~33m with a dark blue low resistivity area, corresponding to YZK01 histogram 27m~31.5m is altered diorite porphyry, locally slightly minor kaolin alteration, and core is silty. YZK02 35.21m~40.06m histogram askaolin, core integrity kaolinitization, strong alteration. It can be seen that the low resistance in the geophysical prospecting results is basically caused by kaolinite alteration. YZK03 hole layout shown in Figure 2, CSAMT depth 108~200m position light green high resistance region, corresponding to the YZK03 histogram 109.3m~130.97m altered granite porphyry and diorite porphyrite, low resistivity zone within the range of 0~108m, especially basic miscellaneous fill, concrete and other goods in the range of 55~65m corresponding to the histogram. YZK04 hole layout shown in Figure 8 shows that the depth 0m~17m range in CSAMT section and transient electromagnetic profile is blue low resistance area, corresponding to YZK04 hole columnar diagram is miscellaneous fill and silty clay, and in this depth, there are phenomena such as collapse hole and water leakage.

Figure 7 line 8 detection results and verifying hole position diagram

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| Table 2 | Sample lithology description results |
|---------|-------------------------------------|
| Hole number | Depth(m) | Lithologic description |
| YZK01 | 0~3.00 | Miscellaneous fill |
| | 3.00~12.40 | Silty clay |
| | 12.40~13.60 | Strong diorite porphyrite |
| | 13.60~24.50 | Diorite porphyrite |
| | 24.50~85.14 | Orite porphyrite |
| YZK02 | 0~3.20 | Miscellaneous fill |
| | 3.20~12.69 | Silty clay |
| | 12.69~16.70 | Weathered granite porphyry |
| | 16.70~35.21 | Granite porphyry |
| | 35.21~40.06 | kaolin |
| YZK03 | 0~22.83 | Miscellaneous fill |
| | 22.83~40.70 | Commercial concrete |
| | 40.70~43.90 | Silty clay |
| | 43.90~45.00 | Commercial concrete |
| YZK04 | 0~3.0 | Miscellaneous fill |
The results of the above borehole verification show that the results obtained by CSAMT and TEM are basically consistent with the results of borehole verification. The physical properties of the low-resistance zone are kaolin alteration and miscellaneous fill, while the physical properties of the high-resistance zone are basically granite porphyry and diorite porphyrite. In addition, It is indicated that the formation is incomplete and the structure is not dense which the four boreholes YZK01~YZK04 have mud consumption through the analysis and verification of the drilling process and drilling results. There are no holes, but there are loose and fissure areas in the four holes and the bottom of the hole, this is a safety hazard, with only a degree of difference. The consumption of the slurry is a proof of the complete degree of formation and the more consumption is, the more the formation is broken and the degree of compaction is worse.

7. Conclusion
The above analysis shows that:

(1) Detection method using CSAMT and transient electromagnetic combination can around the strong electromagnetic interference environment to achieve accurate detection of ground subsidence area, the detection method of CSAMT depth, the effective depth of up to 200~300m, and the abnormal area more accurate judgment, but the relatively low resolution of the transient electromagnetic method in the shallow part of the resolution is better than CSAMT, but the detection depth affected by medium target depth has great influence, credible depth in the range of 100m, blind and shallow have certain 10-20m.

(2) Data processing and interpretation in the process of the two kinds of detection methods, need to determine the boundary conditions with the existing geological data, and adopts the comprehensive analysis to explain the results, so as to achieve the two geophysical methods confirm each other, and ensure the accuracy of detection results, provide a reliable basis for geological interpretation of the results and verify the drilling.

(3) In the vicinity of cities and areas with strong interference, we need to comprehensively consider the terrain and geological conditions, and choose the appropriate detection methods flexibly. When data collection is collected, some anti-interference measures are needed to ensure the quality of data acquisition. The detection practice shows that the CSAMT and the transient electromagnetic method can adapt to the strong interference environment, and the detection results have been verified by drilling, and good results have been achieved.

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