Experimental Research on Distribution Regularity of Stray Current Along Lanzhou Metro Line 2

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Abstract. Taking the soil along the Lanzhou Metro Line 2 as the experimental object, soil samples of Lanzhou Jiaotong University Station, West Railway Station and Yanbei Road Station have been collected. According to the different soil types, drainage net laying of buried pipeline depth, soil depth, etc., an experimental research on the regularities of distribution of stray current was carried out. The experimental results show that (1) the stray current can be effectively reduced by the laying of the currents drainage net; (2) the buried pipeline can strengthen the influence on stray current; (3) the stray current will be smaller with the deepening of the soil depth. Thus, a theoretical reference for the formulation of the corrosion protection scheme for the stray current of Lanzhou Rail Transit Line 2 was provided.

1. Introduction

The influence of stray current corrosion on the urban rail system and surrounding structures has all along been an important factor that confuses the safe operation of urban rail transit[1]-[5]. Therefore, in order to better prevent, control and evaluate the corrosion damage of the stray current, it is necessary to analyze the law of stray current generation and distribution under different environmental conditions[6]-[7]. This paper takes Lanzhou Metro Line 2 (The following is called line 2.) as the object of experimental research, and the soil of three sites including the West Railway Station, the Yanbei Road Station and the Lanzhou Jiaotong University Station is used as the experimental sample. On the basis of the self-designed laboratory test model and the experimental device, the stray current of line 2 was tested[8]. The variation of stray current is obtained with the analysis of measured stray current value caused by different environmental factors (such as different soil structure, the laying drainage net and pipelines, etc.) and its corresponding graphics, which provides the theoretical basis for the design of stray current corrosion protection on line 2.

2. Experimental equipment and texting process

2.1. Experimental equipment

The stray current test simulation device is shown in Figure 1. Experimental equipments are as follows: a plastic container, specifications: length × width × height = 0.5 m × 0.4 m × 0.6 m; a simulation subway traction substation digital DC power supply, model TH-SS3022, the range of 0 ~ 30V; the resistance of the five series connection is 3Ω as the protection resistor Rs; two resistance 1Ω nickel chrome resistance piece laying in the soil surface to simulate the rail; two metal test probes. The avometer A1 is used to measure traction current value whose DC current rating is 10A at test. The
avometer $A_2$ is used to measure the magnitude of the stray current in the soil whose DC current rating is 200μA at test. Some wires.

![Diagram of simulation device](image)

**Figure 1.** Stray current test experiment simulation device.

2.2. Testing process

We collected soil samples respectively at one station of Anning District, Qilihe District and Chengguan District to carry on our experiment according to the direction of Line 2 and the different distribution of soil types in Lanzhou City. Among them, we took samples at Lanzhou Jiaotong University Station in Anning District (ash calcium soil), West Railway Station in Qilihe District (chestnut soil) and Yanbei Road Station in Chengguan District (sandy loam). Stray current tests were carried out on the soil, buried pipes, added currents drainage net, currents drainage net and pipes under different soil conditions (compaction and addition of stratum) respectively. We also studied the influence of laying drainage net and the distribution of stray current at different depth of soil. The characteristics and description of the typical soil are shown in Table 1[10].

| Take Soil Points                  | Soil Type      | Colour   | Composition Characteristics                                                                 |
|----------------------------------|----------------|----------|---------------------------------------------------------------------------------------------|
| Lanzhou Jiaotong University Station | Calcareous soil | Yellow-gray | Calcareous soil is dry soil, moisture content is less, the surface is yellowish gray.         |
| Xikezhan Station                 | Chestnut soil  | Maroon brown | Chestnut soil its main feature is the upper part of the chestnut, the majority of chestnut soil has been classified as soft soil. |
| Yanbeilu station                 | Sandy loam     | Tan      | Sand sandy loam is composed of sand, grains and clay particles of different sizes of mineral particles. Its sand content is more, but also contains a small amount of clay particles and tablets, making it a combination. |

As is shown in Figure 1, the simulation device measures stray current leaked into soil directly by using a metal probe and avometer. During this test, in order to improve the reliability of test results, the values were measured 3 times in each case, and the final measurement results were calculated by the arithmetic mean of 3 measurements.

3. Experimental results analysis

3.1. Effect of drainage network on stray current

In this experiment, we take the soil of the West Railway Station as the experimental sample and keep traction current at 1.22A. Paralleling two nickel chrome resistor wires whose resistance is 1Ω to replace steel rail whose resistance is 0.5Ω. The probe depth of the metal probe remains 4cm and the locomotive distance from traction substation $L= 20$cm. The current drainage net is connected to the
negative pole of the power supply through wires laid at 3cm away from the soil surface. Measuring the influence to stray current on three different soil structures which are original conditions, compaction conditions and laying of stones. The measurement model is shown in Figure 2. The metal probe A is fixed on the positive pole of the power supply, and the stray current value is measured by changing the distance of the metal probe B to simulate different distances from the traction substation. The graph drawn by analyzing the result data is shown in Figure 3.

As can be seen from Figure 3, the stray current decreases obviously after adding the currents drainage net under three different soil structures which are original conditions, compaction conditions and laying of the rock layer compared with the measured stray current without the currents drainage net. The basic properties of the stray current keep the same no matter the currents drainage net is added or not. The extreme point appears near the midpoint of the line and is relatively concentrated;
laying of currents drainage net under different soil structures can reduce the stray current with an obvious effect.

Accordingly, it can be concluded that during the construction of rail transit in Lanzhou, people can greatly reduce the stray current in the soil by laying currents drainage net.

3.2. Effect of currents drainage net laying depth on stray
Take three typical soil of Lanzhou Jiaotong University Station, West Railway Station, Yanbei Road Station as the experiment object, the experimental conditions are: maintain the traction current at 1.22A; the rail resistance should be 0.5Ω; the locomotive from the traction substation L = 20cm. In this experiment, the original soil at each point was taken as the experimental object without changing the soil structure and external conditions. The experimental setup and conditions are the same with the effect of adding currents drainage net to stray current experiment. Under the same conditions, change the currents drainage net laying depth, drainage network laying way and depth as the experimental simulation device shown in Figure 4. Respectively, test stray current distribution under the depth of 2cm, 3cm and 4cm. Finally, analyze the data to obtain stray current rules which are shown in Figure 5.

By analyzing what the Figure 5 shows, laying currents drainage net in different types of soil can reduce stray current and the depth of currents drainage net has a significant impact on reducing its stray current. According to the graph, the deeper the currents drainage net is, the worse the stray current reducing effect becomes. But the laying depth of the currents drainage net has no influence on the basic characteristics (relative concentration, extreme point position, etc.) of stray currents.

All in all, stray current variation rules can provide some theoretical references for the laying of currents drainage net of Lanzhou Metro Line 2. Stray current control through the currents drainage net can be carried out with shallow paving under permitted conditions, so that it can be more effective.

![Figure 4. Experimental simulation device with currents drainage det.](image_url)

(a) West Railway Station original soil plus currents drainage det (b) West Railway Station stray current distribution
3.3. Influence of soil structure on stray current

Maintain the basic conditions of the experiment unchanged: the traction current equals to 1.22A; the rail resistance equals to 0.5Ω; the probe depth of the metal probe keeps at 4cm; the locomotive from the traction substation L = 20cm. Taking three typical soil of Lanzhou Jiaotong University Station, West Railway Station and Yanbei Road Station as samples to carry on the experiment. The stray current of three typical soils under different structures (original conditions, compaction conditions and laying of stratum) was tested respectively. Compaction conditions refer to the original soil height being pressed down 1cm as a benchmark. The laying of the stone layer at a distance of 2cm from the soil surface, laying a fixed thickness about 1cm. Experimental simulation device is shown in Figure 6. The original condition of the soil surface is at 0cm scale, compaction conditions will decrease from 0cm down to scale 1cm, laying stone layer condition is laying from scale 2cm to 3cm, the laying of the thickness is 1cm and the probe depth remains unchanged at 4cm mark. Building the experimental devices shown in Figure 6, the stray current is measured under different conditions. The stray current value, characteristics and law under the corresponding conditions are shown in Figure 7.

It can be seen from Figure 7 that in different types of soil, the stray current of compaction and laying of stratum behave the same pattern. Compaction of the soil can reduce stray current to a small extent, while laying of the stratum can greatly reduce the stray current under the stratum. However, the basic characteristics of stray current (trend, central relative concentration and extreme point position) are still unaffected.
3.4. Effect of soil depth on stray current

Maintain the basic conditions of the experiment unchanged: the traction current equals to 1.22A; the rail resistance equals to 0.5Ω; the probe depth of the metal probe keeps at 4cm; the locomotive from the traction substation L = 20cm. Lanzhou Jiaotong University Station, West Railway Station and Yanbei Road Station were taking as the experimental object. The different depths of the soil were simulated by changing the depth of the metal probe, and then the stray current of the soil at 4 cm, 5 cm, and 6 cm were respectively measured. The relation between stray current and soil depth is shown in Figure 8.

![Graphs showing the effect of soil depth on stray current](image-url)
It can be seen from Figure 8 that the stray current generated in the same soil varies with the depth of the soil. The stray current decreases with increasing distance from the rail, and this phenomenon is observed in different types of soil. Based on this conclusion, it can be known that if the soil depth is deeper, the influence of stray current is relatively small. The metal pipe near Lanzhou Subway Line 2 can be properly buried deeper to reduce the corrosion of stray current.

4. Conclusion

(1) Laying currents drainage net can greatly reduce the stray current in the soil, and the laying of more shallow drainage has obvious effect.

(2) Different types of soil and structure will lead to changes in stray current, so stray current prevention and control design should be more targeted and focused in different regions and environment.

(3) In the soil under the rail, the stray current decreases with the increase of the soil depth, and the appropriate increase of the buried depth when the buried metal body is laid has reduced the corrosion effect.

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