Research on the impact echo technique of quantitative detecting the pre-stressed conduct grouting pumpness

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Abstract: The internal prestressed conduct grouting condition is the key problem in prestressed concrete girder bridge throughout the whole service life. Howeverm, there is no set of certain mature and reliable detection technology. This paper based on the impact echo theory, through the precision acquisition of the impact echo time of the prestressed pipe under the condition of different grouting condition levels. By establishing the relationship model between the grouting fullness degree and the reflection time of the impact echo, to provide the quantitative and accurate of measurement of the full degree of prestressed pumpness detection technique, and service for the maintenance and rehabilitation of bridge engineering. Under laboratory conditions, set the measuring line and measuring point, application of impact echo equipment and calculation models for the detection of grouting plumpness of test beams. The drilling results show: the relative error is better than 5% pre-stressed pipeline grouting plumpness measurement, can satisfy the precision of engineering test requirements.

Introduction

It's generally believed that the deficiency of mortar in pre-stressed pipe is ubiquitous. That produces a lot of diseases such as the corrosion of pre-stressed steel, the stress concentration of anchor head, the loss of pre-stressed as time goes on and so on. It may affect the stress state of the structure, reduce the bearing capacity of bridges, affect the service life of bridges if not detect the using state of pre-stressed steel and evaluate its impact on structural durability. Thus pre-stressed pipe of pre-stressed bridge grouting quality testing is an important segment to ensure the quality of the bridge to satisfy the design requirements and the operation of the reasonable stress state. Pre-stressed steel belongs to concealed work, and grouting quality control is usually only in the pouring process and pouring site. Once the concrete pouring molding, it can not be possible to detect the existence of quality problems. It also increases the cost of future bridge maintenance.

The main methods of detecting the density of slurry in the pre-stressed steel pipe include: impact echo method, ultrasonic method, ground penetrating radar method, ray method, etc. They have their own characteristics [1] . The impact echo method have the advantage that not affected by

the metal pipeline, large measuring range and low operating environment requirements. But the most of existing technology using fast Fourier transform (FFT) can be transformed time domain waveform into amplitude spectrum, so as to obtain the transducer received impact echo frequency. For the judgment of defects still stuck in there, or by experience generally determine the size and position of defects. It is still in the qualitative phase of the defect, which makes the test and results have been unsatisfactory. This study is based on the principle of impact echo, through establish grouting plumpness of pre-stressed pipe and the relation model of impact echo bottom reflection time to present a quantitative method which used for the detection of grouting plumpness in pre-stressed pipe [2、3] .

The establishment of calculation model for the grouting plumpness of pre-stressed pipe

Arrangement of measuring line and measuring point

（1）Calibration line

Arrangement of concrete member calibration line 1along the pre-stressed steel direction on the top surface of concrete member. In order to avoid pre-stressed pipe, line 1 is located at the edge of the distance component 10~20cm.Line 1 also can be arranged on the surface of the concrete member corresponding to the middle position of the middle axis of the two pre-stressed pipelines. The length of the line should not be less than the length of the pre-stressed pipe. Uniform set points on the calibration line, and the distance of the measuring points should between 10~20cm. As shown in Figure 1 [4] .

（2）Detection measuring lines

Measuring line 2 is arrange on the location of the pre-stressed pipe of the concrete member's top surface. The length of line 2 is equal to the length of the pre-stressed pipe. Uniform set points on the calibration line 2, and the distance of the measuring points between 10~20cm. As shown in Figure 1.
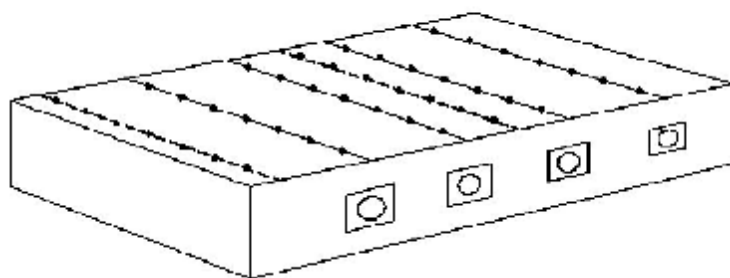

Fig. 1.   Calibration test line and measurement line of concrete component
（**notes：1 is the calibration line，2 is the detection line，·represents the measuring point**）

The average reflection time tp of impact echo of concrete structures

Taking the precast concrete component as the trial object, set the low frequency stress pulse excitation device and the low frequency stress pulse receiver at the measuring point of measuring line 1. When the low frequency stress pulse receiving device receives the resonance wave signal,

the impact echo bottom reflection time t_{pi} of the concrete member is recorded. Move low frequency stress pulse excitation device and low frequency stress pulse receiving device along with the concrete component simultaneously, and it can be used to measure the echo reflection time at each measuring point and calculate its average value which is named as impact echo bottom average echo time t_p.

The reflection time of impact echo of pre-stressed pipeline t_i

In order to measure the pre-stressed pipeline, a low frequency stress pulse excitation device and a low frequency stress pulse receiving device are installed at the measuring points of the impact echo line 2 of the pre-stressed pipeline. It produces low frequency stress pulses that propagate back into the interior of the structure and reflected back to the bottom of the member. The stress wave is reflected back and forth between the top surface of the member, the inner part of the pipe, and the bottom surface of the member. When the bottom reflection time t_i of the resonance wave obtained, the low frequency stress pulse excitation device and the low frequency stress pulse receiving device are simultaneously moved along the impact echo line 2 in the pre-stressed pipeline. Finally, the t_i value of each measuring point should be measured.

The calculation model of the grouting fullness of pre-stressed pipe

Determine the pre-stressed pipe without grouting and grouting under the condition of 50% and 100% (as shown in Figure 2), according to the 1.3 and 1.4 obtain the impact echo bottom reflection time t_p of concrete member and the impact echo bottom reflection time t_i of pre-stressed pipe, it can confirm that the relationship between the specific value of t_i and t_p with grouting plumpness. Then, it could get the relation curve by fitting. Finally, according to the calibration results, the calculation model of the grouting fullness of pre-stressed pipe is obtained. As shown in equation 1:

$$f = Kt+b \quad \text{(equation 1)}$$

Where f is the grouting fullness of pre-stressed pipe (%); K is the time coefficient; t is the specific value of the impact echo bottom reflection time t_i of pre-stressed pipe with the impact echo bottom reflection time t_p of concrete member; b is a relation constant; Among them, when f ≥100%, f=100%, when f≤0%, f=0%.

不灌浆　　　50%灌浆　　　100%灌浆
Fig. 2. Conditions for grouting of pre-stressed pipe

The following is a pipeline 80mm diameter of plastic corrugated pipe, the calculation model of grouting fullness:

$$f = -4.9834t+ 6.7957 \quad \text{(equation 2)}$$

Where K=-4.9834; b=6.7957; when f ≥100%, f=100%, when f≤0%, f=0%.
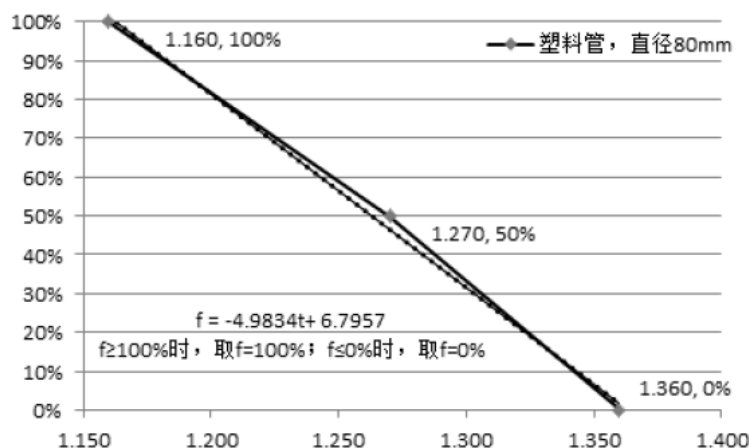
As shown in Figure 3：

Fig. 3.   The fitting curve of grouting plumpness

The degree of grouting of pre-stressed pipe

According to the calculation model of the degree of saturation of the pre-stressed pipe, the grouting fullness of each measuring point is calculated respectively. The grouting degree of each measuring point is connected to form the whole pipe grouting condition [5]. If the grouting fullness difference between the two adjacent points is greater than the specified ratio (usually 10%), it is necessary to increase the number of measuring points between the two measuring points, and then connect the pipeline to reflect the state of grouting.

Detection of grouting fullness of a pre-stressed concrete pipe

A concrete member, length of 1m, thickness of 86cm, with a diameter of 80mm plastic bellows. The calibration of line arrangement at the edge of the concrete component 0.15m position distance, the measuring point distance is 0.1m. The measuring line is arranged on the upper surface of the concrete component corresponding to the middle axis of the pre-stressed pipeline, the measuring point distance is also 0.1m. Calibration line and measuring line adopt the same layout scheme.

Select the excitation frequency of 5.814khz steel hammer. The impact echo bottom contact time of 11 measuring points are demarcated. According to the impact echo bottom reflection time (t_{pi}), It can calculate the mean time(t_p) of reflection of impact echo. Where t_p =0.449ms.

Select the same vibration frequency of 5.814khz steel hammer. The impact echo bottom reflection time of 11 measuring points of   measuring line was measured. As shown in Table 2.

According to the bottom time (t_i) of the impact echo of the measuring line and the Mean time (t_p) of reflection of impact echo together with Calibration equation 2, the grouting fullness condition of each measuring point of pre-stressed pipe can be calculated. As shown in Table 2.

Tab. 2. The time of bottom-finding reflection and the condition of grouting fullness

Measuring point number i	he impact echo bottom reflection time t_{pi}（Unit：ms）	the impact echo bottom reflection time t_i（Unit：ms）	The degree of grouting fullness of each measuring point of pre-stressed pipeline f
1	0.451	0.532	89%
2	0.450	0.536	85%
3	0.450	0.538	82%
4	0.449	0.541	79%
5	0.448	0.543	77%
6	0.450	0.545	75%
7	0.449	0.544	76%
8	0.449	0.540	80%
9	0.447	0.536	85%
10	0.448	0.532	89%
11	0.449	0.530	91%

As can be seen from table 2: The difference between the two measuring points is less than or equal to the specified ratio of 10%. The average pressure value of each measuring point is taken as the average value, and the grouting condition of the whole pipeline is formed.

Analysis of measurement error of grouting fullness

The impact drill is used to drill holes on the pre-stressed pipe, and the grouting degree of the pre-stressed pipeline is verified. As shown in Table 3, the measurement error of pre-stressed pipe grouting fullness is better than 5%.

Tab.3 Measurement error of the grouting fullness degree

Measuring point number i	The degree of grouting fullness of each measuring point of pre-stressed pipeline f calculated value	The degree of grouting fullness of each measuring point of pre-stressed pipeline f Verification value	Relative error of measurement
1	89%	90%	1%
2	85%	81%	5%
3	82%	85%	3%
4	79%	81%	2%
5	77%	80%	4%
6	75%	78%	4%
7	76%	77%	2%
8	80%	78%	3%
9	85%	81%	5%
10	89%	85%	5%
11	91%	87%	5%

Conclusion

In this paper, based on the principle of impact echo, a relational model between grouting fullness of pre-stressed pipe and impact echo bottom reflection time is established, and grouting fullness of pre-stressed pipe is measured quantitatively. It solves the problem that the impact echo method can only be used to determine the defect qualitatively in the existing technology and the results of test have low reliability. Using the method of this paper, the relative error of the measurement of pre-stressed pipe grouting fullness is better than 5% under test conditions. Considering the complex structure of bridge, it is necessary to study the influence of ordinary steel bars, concrete internal defects and multi row pipes on the test results. Through the establishment of the revised model to ensure the accuracy of the test and then put into Existing bridges.

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