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# Research on the Application of Impact Echo Method in the Detection of Grouting Compactness of Hollow Slabs in Bridges

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***Abstract:*** *In response to the issue of compactness detection after bridge hollow slab grouting construction, this article studies the application of impact echo method in bridge grouting compactness detection based on the overhaul and renovation project of Shunhe Elevated Bridge in Jinan City. Through on-site experiments, the feasibility and effectiveness of the impact echo method in detecting the compactness of hollow slab grouting were analyzed. The experimental results indicate that by measuring the propagation speed and reflection characteristics of shock waves, the compactness of the grouting area can be evaluated, thereby improving the quality and efficiency of the grouting project. This study provides important reference and guidance for the compaction testing of hollow slab grouting in the renovation project of Shunhe Viaduct in Jinan City.*

***Keywords:*** *Impact echo method, Hollow slab, Grouting density, Overhaul and renovation project*

## 1. Introduction

Elevated bridges are an important component of urban transportation, but their long-term use has led to increasingly prominent structural problems. Therefore, conducting major repairs and renovations has become an inevitable choice. Bridge grouting is a common maintenance and reinforcement method that fills and solidifies cracks and voids by injecting grout, improving the structural strength and stability of bridges. However, the effectiveness and durability of grouting are often influenced by the compactness of the grouting.

Therefore, accurate evaluation of grouting compactness is crucial for ensuring the quality of grouting engineering. Traditional detection methods often have certain limitations, while the impact echo method has the characteristics of non-destructive, real-time, and accurate, and has broad application prospects in the detection of grouting compactness of bridge hollow slabs. It is widely used in the detection of engineering structures [1].

At present, some studies have explored the application of impact echo method in the detection of grouting density of bridge hollow slabs. These studies mainly focus on the collection and processing methods of impact echo signals, feature parameter extraction and analysis, and the establishment of density evaluation models [2-3]. This article is based on the Shunhe Viaduct in Jinan City, and will provide a detailed introduction to the application of the impact echo method in the detection of grouting compactness of bridge hollow slabs. A scheme for detecting grouting compactness of hollow slabs is proposed, and the application of the impact echo method in the detection of grouting compactness of hollow slabs is studied[4-5].

## 2. Testing method and principle of grouting compactness

### *2.1 Impact echo method*

Impact echo method is a method of evaluating material properties by measuring the reflected signal of shock waves propagating in the material. This method utilizes an impact device to generate shock waves, receive echo signals through a detector, and evaluate the physical properties of the material by

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analyzing the characteristics of the echo signals.

By analyzing the presence, strength, and propagation time of the excitation signal reflected from the corrugated pipe and the opposite beam side, the presence and morphology of defects in the corrugated pipe below the test point can be determined[6]. This detection method has high accuracy, strong resolution, and a wide range of applications, and is currently the most commonly used. However, this method takes a long time and is greatly affected by the position of the bellows.

The detection method of the impact echo method mainly includes the following steps:

(1) Impact source generation

Firstly, an impact source, such as an impact hammer or vibrator, is applied to the surface of the hollow slab of the bridge to generate shock waves.

(2) Echo signal reception

Receive the echo signal through sensors and transmit the signal to the data acquisition system for processing.

(3) Echo signal processing

Filter, amplify, and sample the received echo signal to improve signal quality and accuracy.

(4) Feature parameter extraction

Extract feature parameters such as arrival time, amplitude, frequency, etc. from the processed echo signal to evaluate the compactness of the grouting fluid.

(5) Density evaluation

Based on the extracted feature parameters, use relevant models or empirical methods to evaluate and judge the compactness of the grouting fluid[7].

### *2.2 Principle of Impact Echo Method*

The impact echo method is a non-destructive detection technology based on the principle of echo. The shock wave generated by an external shock source propagates through the material, and the echo signal is received by the sensor[8]. Then, the characteristic parameters of the echo signal are analyzed to evaluate the performance or defects of the material. In the detection of the compactness of bridge hollow slab grouting, the impact echo method can be used to detect the compactness of the grouting fluid.

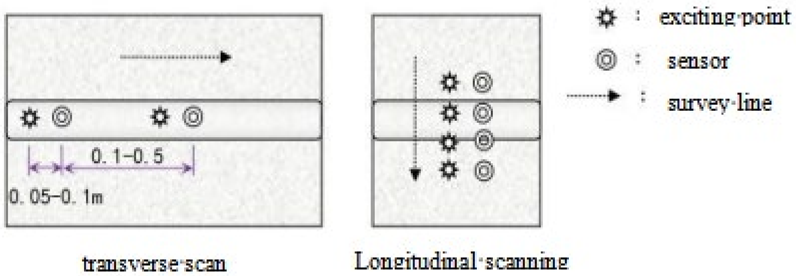


*Figure 1: Schematic diagram of the scanning method using the impact echo method*

In the detection of the compactness of bridge hollow slab grouting, when the impact source acts on the surface of the hollow slab, the shock wave will propagate and reflect in the grouting fluid. The echo signal contains information about the grouting fluid[9]. Evaluate the compactness of the grouting fluid by analyzing characteristic parameters such as the arrival time, amplitude, and frequency of the echo signal. As shown in Fig 1, the scanning method of the impact echo method is illustrated. Along the top or side of the pipeline, continuous testing (excitation and reception) is conducted in the form of scanning, and the condition of grouting inside the pipeline is tested through the characteristics of the reflected signal.

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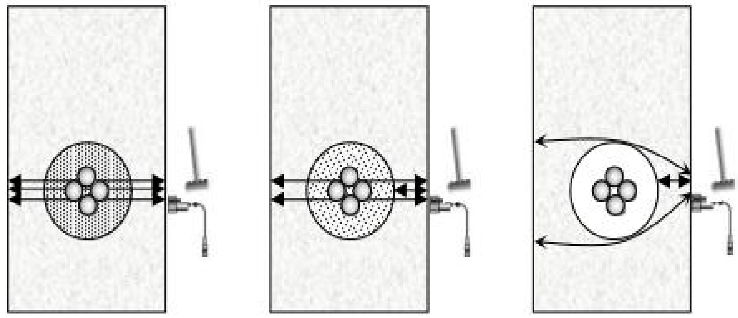


*Figure 2: Schematic diagram of impact echo method test principle*

The presence and type of grouting defects can be determined based on the presence or absence of reflected signals at the corrugated pipe position and the length of reflection time at the bottom of the beam[10]. When there are defects in pipeline grouting, the elastic waves with excitation will reflect at the defect (the theoretical basis of IE method); When the excited elastic wave passes through the defect, it takes longer to reflect back from the opposite side of the beam than in the densely grouted area, and its equivalent wave velocity (twice the beam thickness/round-trip time) slows down (the theoretical basis of the IEEV method); When the half wavelength of the structural free vibration generated by the excitation signal is close to the buried depth of the defect, the reflection of the defect and the free vibration may generate resonance, causing the half wavelength of the free vibration to approach the buried depth of the defect (i.e. resonance offset, the theoretical basis of the IERS method), as shown in Fig 2.

## 3. Project overview

The Shunhe Viaduct in Jinan City is one of the important transportation arteries in the urban area. With the increase of traffic volume and the increase of bridge age, this bridge has certain structural safety hazards. In order to ensure the reliable operation and safety of the bridge, Jinan City has decided to carry out the major repair and renovation project of the Shunhe Viaduct. This paper is based on this project to study the application of impact echo method in the detection of grouting density of bridge hollow slabs.

The Shunhe Viaduct consists of five parts: the north-south main bridge, the Yuhan Interchange South and North bridges, the main bridge ramp, and the Yuhan Interchange ramp, with a total length of 9390.125m. Among them, the length of the north-south main bridge is 5050.685m (excluding tied arch bridges), the length of the south and north bridges of the Yuhan Interchange is 1521.4m, the length of the main bridge ramp is 2179.51m, and the length of the Yuhan Interchange ramp is 638.53m. The lower part is a column pier with a pile foundation. It is planned to carry out major repairs and renovations to the bridge. This maintenance project runs through the Tianqiao District and Shizhong District, starting from the Yuhan Interchange in the south and reaching the tie arch bridge across the railway and the 57th joint on the north side of the tie arch bridge in the north.

The main locations for this inspection include the main line of Shunhe Viaduct, spans 1-102, Yuhan Interchange, and Ramp Bridge, with a total length of 5631 meters.

## 4. Detection Scheme

### *4.1 Implementation steps*

(1) Select the appropriate impact echo instrument

Based on the size and material characteristics of the bridge, determine the testing area and the density requirements of the grouting fluid, and select suitable impact sources and sensors. The instrument should have the characteristics of high accuracy and stability, and be able to accurately measure the propagation speed and reflection characteristics of shock waves. This article uses a multi-functional testing instrument for prestressed concrete beams for testing.

(2) Prepare test samples

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Select representative sample points in the bridge grouting area and prepare test samples. The sample should include different depths and positions of the grouting area to comprehensively evaluate the compaction of the grouting.

(3) Impact echo signal acquisition

Using selected shock echo instruments, conduct shock echo testing on sample points, receive echo signals through sensors, and transmit the signals to the data acquisition system, recording the propagation speed and reflection characteristics of the shock wave.

(4) Echo signal processing

Filter, amplify, and sample the received echo signal to improve signal quality and accuracy.

(5) Data analysis

Analyze and process the test data, evaluate the compactness of the grouting area based on the propagation speed and reflection characteristics of the shock wave, and use statistical methods and image processing techniques to analyze the data.

(6) Density evaluation

Based on the results of data analysis, evaluate the compactness of the bridge grouting area, analyze the advantages and limitations of the impact echo method in bridge grouting compactness detection, and propose suggestions for improvement and further research.

### *4.2 Parameter settings*

In the testing of the compactness of hollow slab grouting, the following parameters need to be reasonably set:

(1) Impact source energy

Based on the properties of the grouting fluid and the characteristics of the hollow slab, select an appropriate shock source energy to ensure that the shock wave can fully propagate and reflect.

(2) Sensor position

Determine the position of the sensor so that it can receive the echo signal and minimize interference and noise as much as possible.

(3) Sampling frequency

Select an appropriate sampling frequency based on the characteristic frequency of the echo signal to ensure accurate signal acquisition and processing.

## 5. Experimental research results

15 units of the Shunhe Viaduct Overhaul and Renovation Project were selected, with a total of 12 measurement points as the analysis objects. The density test results are shown in Table 1.

Through the detection of cloud images, it can be seen that the impact echo method has high feasibility and accuracy in detecting the grouting density of bridge hollow slabs. By analyzing the characteristic parameters of the echo signal, the quality of the grouting process can be evaluated in real-time. The characteristic parameters of echo signals under different densities have significant differences, which can be used to determine whether the grouting quality of bridge hollow slabs meets the requirements.

The experimental results indicate that the impact echo method can accurately evaluate the compactness of grouting in hollow slabs. There are differences in the characteristics of echo signals under different grouting densities, which can be used as a basis for judging the quality of grouting. It can be inferred that compared with traditional detection methods, the impact echo method has significant advantages in detection speed and accuracy.

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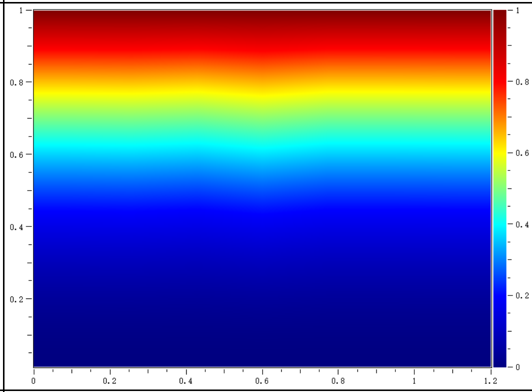
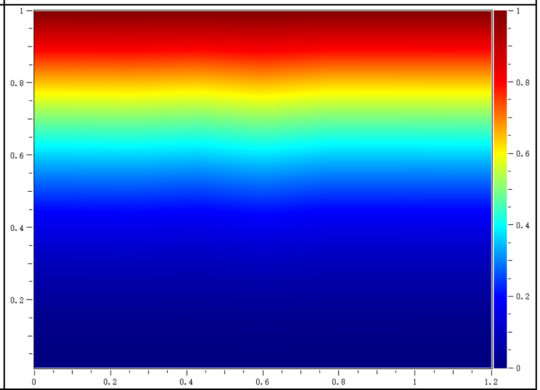
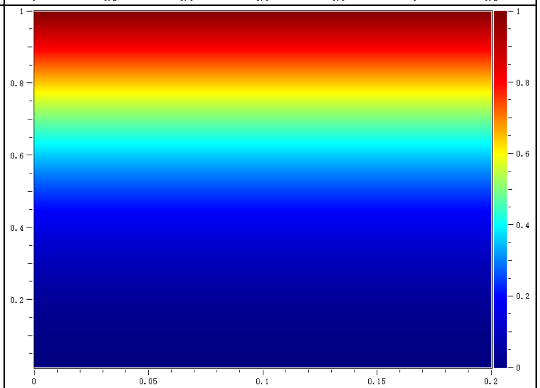
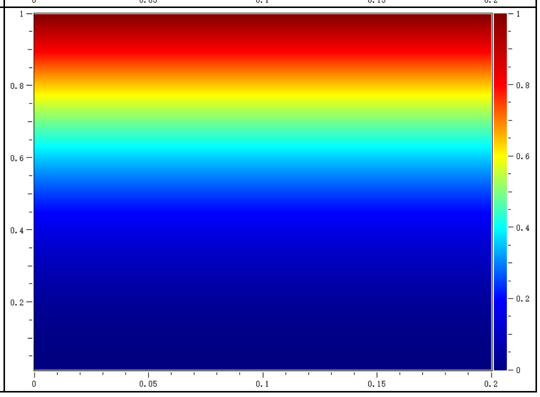
*Table 1: Summary of Test Results*

| Serial Number | Joint number | Pier number | Single beam grouting position | detection result | Detection cloud map |
|---|---|---|---|---|---|
| 1 | 15 Serial | 69 # pier | Left outer side of southern end | No obvious defects were found within the detection range |  |
| 2 | | 69 # pier | Left side inner side of southern end | No obvious defects were found within the detection range |  |
| 3 | | 69 # pier | Outer right side of southern end | No obvious defects were found within the detection range |  |
| 4 | | 69 # pier | Inside the right side of the southern end | No obvious defects were found within the detection range |  |

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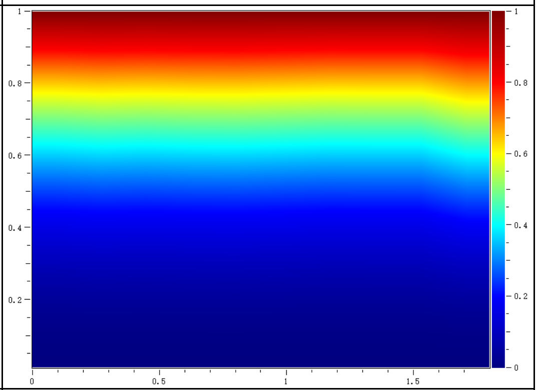
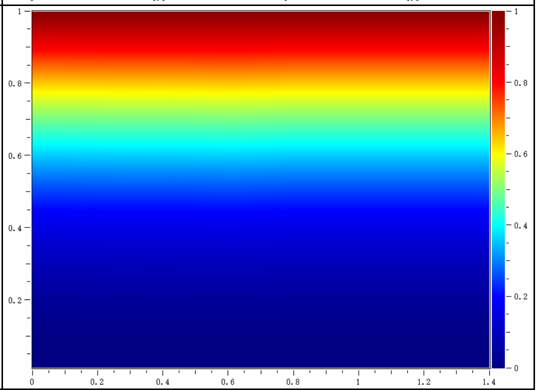
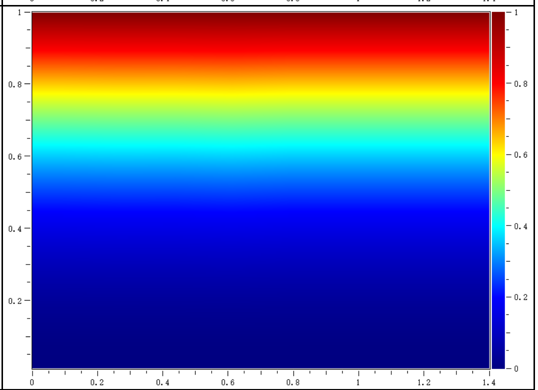
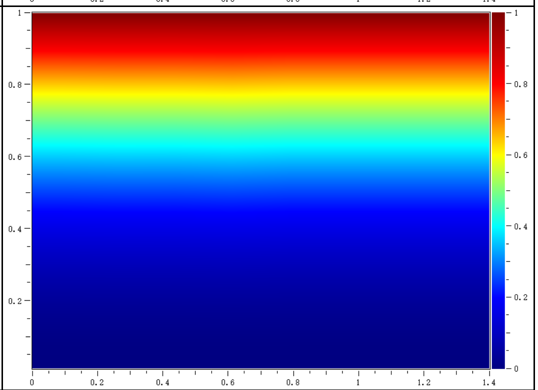
| Serial Number | Joint number | Pier number | Single beam grouting position | detection result | Detection cloud map |
|---|---|---|---|---|---|
| 5 | 15 Serial | 69 # pier | Outside the left side of the northern end | No obvious defects were found within the detection range |  |
| 6 | | 69 # pier | Inside the left side of the northern end | No obvious defects were found within the detection range |  |
| 7 | | 69 # pier | Outer right side of the northern end | No obvious defects were found within the detection range |  |
| 8 | | 69 # pier | Inside the right side of the north end | No obvious defects were found within the detection range |  |

## 6. Conclusion

This article studies the application of impact echo method in the detection of bridge grouting compactness. Based on the renovation project of Shunhe Viaduct in Jinan City, through reasonable implementation steps and parameter settings, combined with the detection method and principle of impact echo method, accurate evaluation of the quality of hollow slab grouting has been achieved. The main conclusions are as follows:

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(1) By measuring the propagation speed and reflection characteristics of shock waves, the compactness of the grouting area can be evaluated, thereby improving the quality and efficiency of the grouting project.

(2) The use of multi angle impact echo method can improve the accuracy of its measurement, and combined with image processing technology, automatic analysis and interpretation of echo signals can be achieved.

(3) However, the impact echo method still has some limitations in detecting the compactness of bridge grouting, such as its dependence on material properties and interpretability of test results. Therefore, future research can further improve the accuracy and reliability of the impact echo method, and compare and validate it with other detection methods to improve the quality and sustainability of bridge grouting engineering.

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