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Comparative study between acoustic wave transmission method and low strain reflection method to detect the integrity of piles

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Abstract. More than 400 friction piles of a highway bridge in northern China were detected by both acoustic transmission method and low strain reflection method,while the integrity levels of the piles were judged different by the two methods, they were finally identified by means of drilling core-taking or drilling television. The misjudgment of the acoustic transmission method and the low strain reflection method are counted, and classified statistics were conducted according to the location and type of defects, while the reasons of misjudgment are analyzed. Some suggestions for the comprehensive application of the acoustic transmission method and the low strain reflection method are put forward, which can be for the reference of the testing technician.

1. Introduction

Acoustic transmission method and low strain reflection method are the two most commonly used nondestructive testing methods in the field of highway bridge pile integrity testing. The low strain reflection method is a qualitative method, which is limited by geological conditions and requires the inspectors to have rich engineering experience. Therefore, it is gradually neglected by the bridge engineering inspectors. The results of the acoustic wave transmission method are intuitive, but the detection process is greatly affected by the acoustic measurement pipe, so although it is gradually widely used in the engineering field,its criterion is mainly qualitative, too many coring verifications have a certain influence on the project schedule and cost control.

In recent years, the shortcomings of the acoustic transmission method and the low strain reflection method have been noticed. Some researchers tried to combine the advantages of the two methods for comprehensive detection.

In northern China, the length of piles in highway bridges is mostly between 18m and 36m,and the geological conditions are relatively simple. Silt soil is the main layer,which is suitable for detection by low-strain reflection method. More than 400 piles are detected by both the low strain reflected wave method and sound wave transmission method. When the judgements are different,drilling core-taking technology and drilling camera are adopted to verify the results,the statistical analysis results can be referenced for the selection of pile non-destructive testing method,and further research direction is proposed.

2. Contrast detection scheme

Since the relationship between pile integrity level and pile defects (category and degree) is not defined in the current code,the response degree of the test data of low strain method,acoustic transmission method and drilling core method,is different to different pile defects. Even for the same defect,different conclusions may be drawn. Among the three methods mentioned above,the core drilling method is the most intuitive and often used as an arbitration method in practical engineering applications. In this paper,the evaluation results of the drilling core method are also used as the final result,while the actual defects of pile foundation and its bearing capacity and durability are not discussed. All of them are subject to the inspection regulations and specifications. It needs to be noted that since there is no operation procedure for coring method in the technical specification for dynamic testing of foundation piles in Highway Engineering (JTG / tf81-01-2004),a comparative detection scheme is developed in this paper in combination with the relevant contents in the technical specification for detection of building foundation piles (JGJ 106-2014).

(1) The acoustic transmission method and low strain reflection method are used to detect the same pile in the same time and if the judgment results of the two methods are consistent,it is recognized as the final result; if the two judgment results are inconsistent,the drilling group information is used for the final judgment,meanwhile,high-definition digital borehole camera technology is applied to make sure no misjudgment are made by drilling group information itself. As there is no relevant standard for the identification of pile foundation type by HD digital borehole camera technology,it was taken as a supplement to the core drilling method in this study. However,in practical engineering,the quality of core samples is usually disturbed by bad drilling bit and incorrect operation,so the fine defects such as pile shaft cracks might be ignored. At the same time,the break and loose of the core samples created by bad drilling bit and incorrect operation may be considered as the defect of foundation piles,and that’s why HD digital borehole camera technology is used to avoid the misjudgment and omission by the drilling group information.

(2) In order to eliminate the influence of the defect of the acoustic tube in the acoustic transmission method,if the defect is detected by the acoustic transmission method,the acoustic pipe is rinsed with clean water,and the re-inspection result is taken as the final judgment result.

(3) The layout of coring holes: The defect position reflected by the acoustic transmission method and the correlative criterion are taken into account to decide the selection of coring position. When the acoustic transmission method reflects that a certain section has defects or the defects are more serious than other sections,coring hole shall be conducted at the same section position,and the rest core holes shall be arranged in accordance with the technical code for detection of building foundation piles (JGJ 106-2014). The specific location of the coring holes is illustrated in Fig. 1.

Two coring holes are provided for each pile,and the one with more serious defects is taken to determine the integrity grade of the foundation pile.

(4) After the data collection,the basic geological data were provided to two experienced civil engineers,while the data collected with the low strain detection method or the acoustic transmission method will be provided to only one engineer,and they judged the integrity grade of the foundation pile independently according to the data they have.

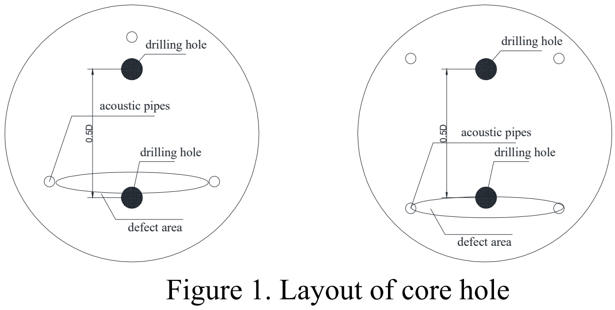

Figure 1. Layout of core hole

(5) When the inspection is finished, the integrity grades of the foundation pile are divided into three categories. The misjudgment of the two methods are counted respectively.

3. Results of contrast tests

In this project,428 piles are detected with both low strain detection method and acoustic transmission method,394 of which are consistent with each other, accounting for 92.1%. And among them, there are 356 piles of class I, accounting for 83.2% of the total number of piles inspected; 36 piles of class II, accounting for 8.4% of the number of piles inspected; 2 piles of class III or below, accounting for 0.5% of the number of tested piles. And there are 34 piles with inconsistent identification by the two detection methods, accounting for 7.94% of the total inspected piles. The details are shown in Table 1.

It can be seen that the low strain reflection method and the acoustic transmission method have good consistency in judging the integrity of the pile, especially for the foundation pile with good integrity, whose integrity grade are above class II. And the possibility of making wrong judgment by the two methods at the same time is extremely low.

Table 1. Summary of comparative test results

Pile integrity category	Quantity (piece)	Percentage of total（%）
I	356	83.18
II	36	8.41
III and below	2	0.47
Inconsistent detection made by the two methods	34	7.94

In order to further clarify the misjudgment of the two detection methods and analyze the causes of the misjudgment, the core drilling and high-definition digital borehole camera technology are applied to the 34 piles with inconsistent results of the two detection methods to get the final judgment. At the same time, the drilling core method is also used for the piles whose integrity level is class III and below by low strain reflection method or acoustic transmission method, and the pile integrity grade is evaluated by drilling core method as the final test result. The results showed that: 25 piles were misjudged by the acoustic transmission method, and 10 piles were misjudged by the low strain reflection method, while 1 pile was misjudged by both the two detection methods. The details are shown in Table 2 and table 3.

Table 2.List of misjudgment by acoustic transmission method

Pile integrity category	Judgment by acoustic transmission method	Quantity (piece)	Reasons of misjudgment
I	II	2	The concrete at the top of the pile is separated from the acoustic pipe during the removal of the pile head,resulting in abnormal acoustic data of one profile.
I	III and below	2	The concrete at the top of the pile is separated from the acoustic pipe during the removal of the pile head,resulting in abnormal acoustic data of 2 or more than 2 profile.
II	I	1	The partial deviation of the acoustic pipe layout is serious,and the defect location is not in the effective detection section range of the acoustic pipe.
II	III and below	20	The results of the acoustic transmission method show that there are defects in several sections,and the actual coring verification shows that the defect range is smaller than the actual response of the acoustic transmission method. Beside,one pile foundation coincides with the misjudgment of low strain emission method.
III and below	I	0	
III and below	II	0	
Total		25	——

Table 3. List of misjudgment by low strain detection method

Pile integrity category	judgment by low strain reflection method	Quantity (piece)	Reasons of misjudgment
I	II	1	It may be induced by the change of geological conditions,the acoustic data at the same reflection position is normal,and there are no holes or cracks in coring and high-definition borehole photography.
I	III and below	0	
II	I	0	
II	III and below	1	The 36m long friction pile has defects at about 9m,reflecting vibration in the same direction,and the reflection at the bottom of the pile is not obvious. The actual drilling core and excavation detection show that only one side of the pile has concrete defects,reaching the interior of the reinforcement protection layer.
III and below	I	5	The thickness of sediment at the bottom of friction pile with a length of 32~36m are about 0.6 ~ 1.0m. The wave velocity of low strain reflection method is not obvious abnormal compared with other complete pile foundation.
III and below	II	2	These two friction piles are about 36-40 m long. The data collected by low strain reflection method show a Syntropism about 10 m away from the pile top, while the reaction of pile bottom is not obvious. However, the reflection of other normal pile is not obvious too.
Total		9	

Further analysis of the above chart shows that：Although the acoustic transmission method and the low strain reflection method maintain good consistency in the pile integrity identification, the biggest reason is that the integrity of the piles is complete. When the pile integrity is defective, the inconsistency between the two methods becomes very large: there are about 67 piles with defects in total in this project, while 34 piles are not consistent with this two inspecting method, accounting for 50%. Further analysis show more characteristics as follows:

(1) In the cases of misjudgment by acoustic transmission method,8% of the cases judged class I pile as class IIpile,8% judged classIpile as class III pile, and 80% judged class II foundation pile as class III or below. In other words,96% pile integrity grade of the cases were judged lower than they actually were. Another 4% of the foundation piles are classified as class I piles whose integrity grades were actually II. And the reason for this phenomenon is that the buried acoustic pipe is obviously deviated, and more than 50% of the cross-section of the pile body is beyond the detection range of the acoustic tube.

(2) In the cases of misjudgment by low strain reflection method,11% of the cases judged class I pile as class IIpile,11% of the cases judged classIIpile as class III pile, which means that 22% of piles integrity grade of the cases were judged lower than they actually were. And for Another 78% of the foundation piles whose integrity grades were actually III or below,56% of the piles were classified as class I, and 22% of the foundation piles were classified as class II. In other words,78% of piles integrity grade of the cases were judged higher than they actually were. The biggest reason for the misjudgment by low strain reflection method is the change of geological conditions, which cannot be fully identified.

(3) In general, the acoustic transmission method tends to judge the pile integrity lower than they actually were, while the low strain reflection method tends to judge the pile integrity higher.

(4)In addition, there are some conclusions that can not be drawn by statistical data. For example, all the real pile defects reflected by the acoustic wave curve of the acoustic transmission method are reflected in the low strain reflection curve. The main reason for the inconsistency between the two methods is the difference of the evaluation criteria.

(5) However, there is no relationship between the accuracy of the acoustic transmission method and the defect location of the pile, while the misjudgment of the low strain reflection method has a greater relationship with the defect location. According to the statistical data,the low strain reflection method has a higher probability of missing judgment or slight judgment for the defects located in the lower part of the pile (especially the defects at the bottom of the pile),while the probability of misjudgment for the defects located at the upper part of the pile is relatively small.

4. Conclusions

Through comparing the low strain reflected wave method and acoustic wave transmission method for more than 400 foundation piles in the supporting project,the following conclusions can be preliminarily drawn: for the intact foundation piles,the probability of misjudgment by various methods is low; for the foundation piles with defects,various detection methods can effectively reflect the defect location,but the probability of misjudgment is higher when using single method. In particular,the acoustic transmission method tends to re judge,and the low strain reflection method is more prone to light judgment or missing judgment. The probability of misjudgment and missed judgment is related to the defect location.

Based on the above statistical analysis,the following suggestions are put forward for the comprehensive application of low strain reflection method and acoustic transmission method in pile integrity detection.

（1）For the pile with intact pile body,the possibility of misjudgment caused by both acoustic transmission method and low strain method is small. Since the acoustic transmission method is more intuitive,the detection results of acoustic transmission method are preferred to be adopted except for the serious deviation of acoustic pipe layout.

（2）For the pile foundation with defects in the pile body,if the defect is located at the bottom of the pile or the lower part of the pile,in principle,the detection results of the acoustic transmission method shall be prevailed,and further coring verification shall be conducted if necessary. And if the defects are located in the middle and upper parts,the evaluation results of the low strain reflection method shall be referred to in principle.

In general,the range of defects that can be detected by different detection methods is not the same,and there is no clear standard for the acceptable defects of piles with different integrity categories. Therefore,there is still a lot of work to do to detect the integrity categories of piles by non-destructive methods.

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