Testing and Analysis of Vibration Impact on High-Rise Residential Environment

Zhaoshuan Chen[1*], Yufeng Xu[2], Qilong Wang[2]

[1] Deepfoundation Engineering Scientic & Technology Co.. Ltd.. Shunde, China
[2] South China University of Technology, Guangzhou, China
czs2001@126.com

Abstract. As cities continue to develop and urban buildings increase in number, the issue of environmental vibration affecting urban structures is becoming more prevalent. This article takes as its background the vibration issues arising from the construction of surrounding foundation pit piles for a certain high-rise reinforced concrete residential building. It introduces the testing methods for environmental vibration, presents the results of vibration testing, evaluates these results, and analyzes whether the vibrations generated by the foundation pit pile construction will cause damage or safety issues for residential buildings. The assessment methods in this article can provide valuable references for similar projects.

Keywords: Environmental Vibration; High-Rise Residential Buildings; Vibration Testing; Vibration Assessment.

1 Introduction

With urban development constantly upgrading and renovating, the issue of urban buildings being affected by environmental vibrations is becoming increasingly common[1-2]. Major sources of environmental vibrations include construction activities such as pile driving and blasting, as well as transportation operations like trains and subways, and the use of industrial equipment such as power machinery.[3] These vibrations not only adversely affect the performance of precision instruments but also pose comfort issues for people living inside buildings.[4] Moreover, they can cause minor damage to adjacent buildings and in severe cases lead to varying degrees of structural damage, potentially resulting in safety accidents. To prevent construction vibrations from harming building structures, China has promulgated the "Code for Acceptance of Constructional Quality of Building Vibration" (GB50868-2013), providing relevant technical guidance for addressing issues caused by environmental vibrations.

This article takes the background of vibration issues in a certain high-rise reinforced concrete residential building caused by nearby foundation pit pile construction. It introduces the testing methods for environmental vibrations, presents

W. Guo et al. (eds.), *Proceedings of the 3rd International Conference on Green Building, Civil Engineering and Smart City (GBCESC 2024)*, Advances in Engineering Research 264,
https://doi.org/10.2991/978-94-6463-728-1_59

the results of vibration tests, evaluates these results, and analyzes whether the vibrations caused by pile construction will damage residential buildings and pose safety issues.

2 Purpose of Vibration Testing

A certain high-rise residential building is a completed reinforced concrete structure, consisting of 29 above-ground floors and one basement level. The foundation utilizes cylindrical piles with a diameter of 500 mm and a wall thickness of 125 mm, with pile lengths ranging from 55 to 60 meters. The structure employs a frame-shear wall system. Currently, there is a support construction underway for a pit on the south side of the residential building, using PRC prefabricated piles with a dual-support scheme. The PRC piles are φ 800 with a wall thickness of 130 mm and a length of approximately 30 meters. The inner distance from the pile to the existing underground wall of the completed structure ranges from 1.05 to 3.45 meters. During pile construction, significant vibrations were observed in the completed residential building. To ensure the safety of the residential structure, it is necessary to conduct vibration testing on the existing residential building to determine if the vibrations from pile construction meet the relevant requirements.[5] Based on the test results, measures may be required to mitigate the impact of vibrations on the building. The layout of the foundation pit and existing buildings is shown in Figure 1.

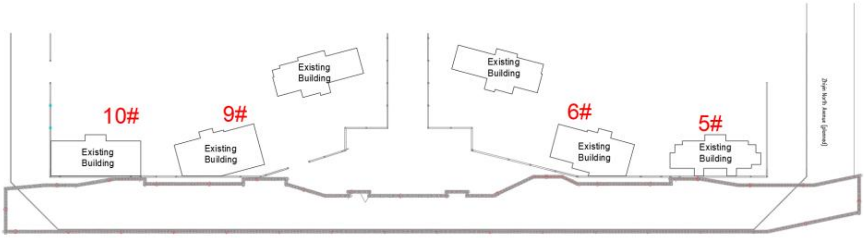

Fig. 1. Plan of Foundation Pit and Existing Buildings

3 Methods of Vibration Testing

3.1 Basis of Testing

(1) "Code for Acceptance of Constructional Quality of Building Vibration" [6] (GB50868-2013)

(2) "Methods for Measuring Environmental Vibration in Urban Areas" [7] (GB 10071-88)

The permissible vibration values in the time domain for the impact of infrastructure such as pile driving and vibroflotation on building structures

Building Type	Permissible Peak Vibration Velocity at the Top Floor Level	Permissible Peak Vibration Velocity at the Foundation Level		
	1Hz~100Hz	1Hz~10Hz	50Hz	100Hz
Industrial Buildings, Public Buildings	12.0	6.0	12.0	15.0
Residential Buildings	6.0	3.0	6.0	8.0
Buildings that are sensitive to vibrations, have protective value, and cannot be categorized into the aforementioned two types	3.0	1.5	3.0	4.0

Fig. 2. The permissible vibration values in the time domain for the impact of infrastructure such as pile driving and vibroflotation on building structures

3.2 Test Layout and Test Conditions

According to the provisions of "Code for Acceptance of Constructional Quality of Building Vibration" (GB50868-2013) sections 8.0.1 to 8.0.2, the frequency range for evaluating the impact of construction vibrations on building structures should be from 1 Hz to 100 Hz. Time-domain signal testing of vibration velocity at the foundation and top floor of the building structure should be conducted in both vertical and horizontal directions along two principal axes. Evaluation criteria should consider the maximum peak values and their corresponding vibration frequencies among these three directions.

Following these specifications, 5 measurement points are set up at the base level of the test building structure, and 4 measurement points are positioned at the top level. Vibration meters are used to assess the vibration levels at each point during pile construction, capturing vibrations in the horizontal directions perpendicular and parallel to the working face of the piles, as well as in the vertical direction.

In this high-rise residential community, buildings 5#, 6#, 9#, and 10# are located near the pit support construction area. These four residential buildings share similar structural forms. Considering that Building 10# is closest to the construction of the pit support piles and likely experiences the greatest impact from pile vibrations, Building

10# is selected as the subject for evaluating the effects of pile vibrations. The layout of vibration measurement points is depicted in Figures 3 to 4.

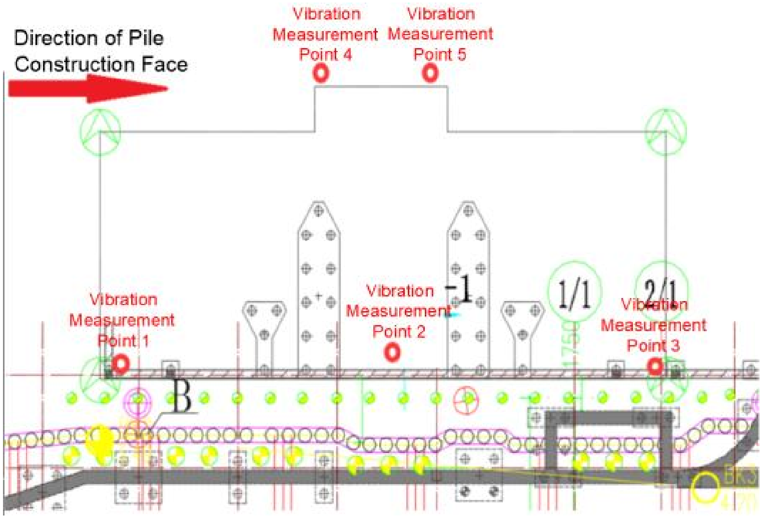

Fig. 3. Vibration Test Point Layout Diagram (Ground Floor)

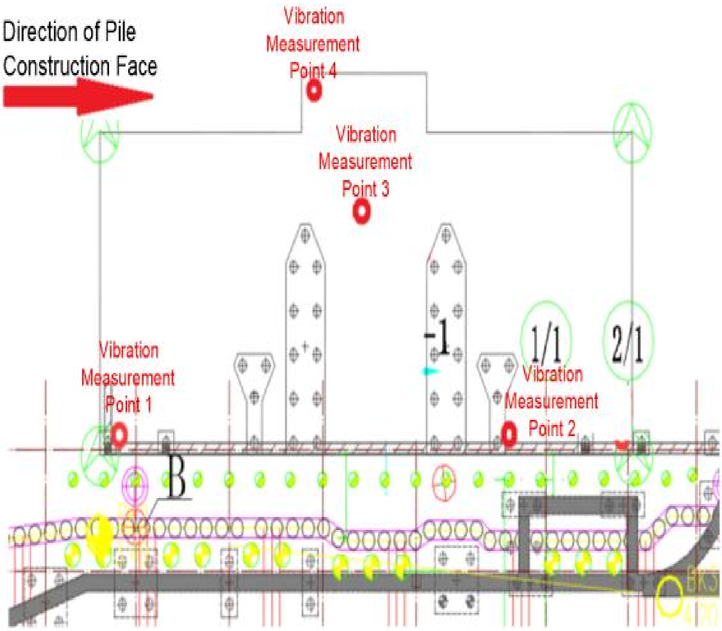

Fig. 4. Vibration Test Point Layout Diagram (Top Floor)

3.3 Testing Equipment

(1) The testing equipment includes: sensors, integrators, data acquisition cards, and computers.

(2) Other materials include various installation materials.

For this test, the INV series intelligent signal acquisition processing and analysis instrument produced by Beijing Oriental Vibration and Noise Technology Research Institute is used, and the signal analysis employs DASP2006 Engineering Edition software. The measurement frequency range of the vibration measurement and analysis instrument complies with the relevant provisions of the current national standard "Code for Acceptance of Constructional Quality of Building Vibration" (GB50868-2013).

3.4 Principle of Testing

The process of vibration testing for this occasion is illustrated in Figure 5.

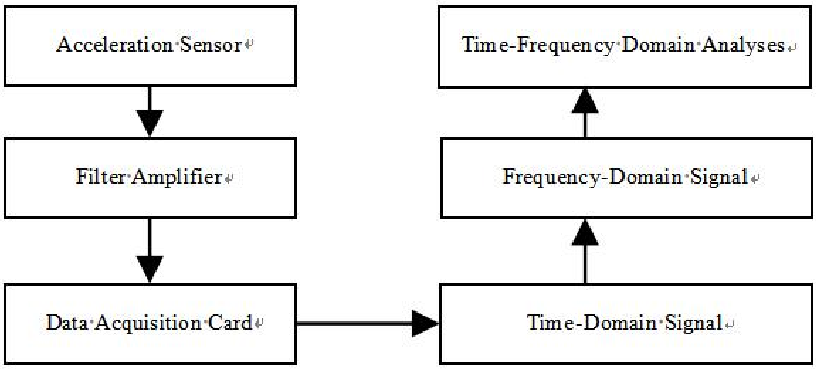

Fig. 5. Flowchart of Vibration Testing

4 Testing Evaluation Analysis Methods

According to the "Code for Acceptance of Constructional Quality of Building Vibration" (GB50868-2013), Chapter 8, sections 8.0.1 to 8.0.2, the evaluation of the impact of construction vibrations on building structures should be within the frequency range of 1Hz to 100Hz. For vibration velocity time-domain signal testing of building structure foundations and top floor surfaces, measurements should be taken in both vertical and horizontal directions along the two principal axes. Evaluation criteria should consider the maximum peak values of these measurements and their corresponding vibration frequencies.

Specifically, when using methods such as pile driving with a hammer, dynamic compaction, or vibroflotation for ground treatment, the allowable vibration values in the time domain affecting building structures should be determined according to the specified table in the standard.

5 Analysis of Test Results

5.1 Principle of Testing

From Table 1, it is noted that during the construction process involving pile driving around residential building 10#, the vibration frequency at the foundation level was 18.75 Hz. According to regulations, this corresponds to an allowable peak velocity of 3.66 mm/s at the foundation level. The actual peak velocity measured at the foundation level of building 10# was 2.25 mm/s, which is below the allowable peak velocity.Similarly, during the pile driving process around building 10#, the vibration frequency at the top floor level was also 18.75 Hz. The allowable peak velocity for the top floor structure was determined to be 6.00 mm/s. Measurements taken at the top floor level recorded a peak velocity of 4.09 mm/s, which is below the allowable peak velocity for the top floor structure.These results indicate that during the construction activities involving pile driving around building 10#, both at the foundation and top floor levels, the measured vibrations were within permissible limits as specified by the regulations.

Table 1. Vibration Test Results and Evaluation Table

Foundation Level Measurement Point	Maximum Vibration Velocity (mm/s)				Corresponding Vibration Frequency (Hz)	Permissible Vibration Velocity (mm/s)	Meets Requirements
	Vertical	Horizontal 1	Horizontal2	Max	Frequency Corresponding to Maximum Vibration		
Foundation Level 1	1.25	1.18	1.97	1.97	18.75	3.66	Yes
Foundation Level 2	2.15	1.39	2.02	2.15	18.75	3.66	Yes
Foundation Level 3	2.25	1.07	1.76	2.25	18.75	3.66	Yes
Foundation Level 4	1.15	1.28	1.71	1.71	18.75	3.66	Yes
Foundation Level 5	1.65	1.07	1.91	1.91	18.75	3.66	Yes
Top Floor 1	2.3	3.32	1.97	3.32	18.75	6.00	Yes
Top Floor 2	1.6	3	2.17	3	18.75	6.00	Yes
Top Floor 3	2.2	3.69	2.28	3.69	18.75	6.00	Yes
Top Floor 4	2.8	4.09	1.28	4.09	18.75	6.00	Yes

5.2 Test Analysis

(1)In the structural vibrations observed in Building 10# of a certain high-rise residential complex due to adjacent excavation support pile construction, the related test results comply with the requirements of the "Code for Acceptance of Constructional Quality of Building Vibration" (GB50868-2013). It can be considered that the vibrations caused by pile construction did not damage Building 10#, and the structural safety risk due to pile construction vibrations is relatively low for this building.

(2) Within this high-rise residential complex, Buildings 5#, 6#, 9#, and 10# are located near the excavation support construction area. These four residential buildings have similar structural forms. Building 10# is closest to the excavation support pile construction site. Therefore, the vibration test conclusions for Building 10# can serve as a reference for assessing the vibration safety of Buildings 5#, 6#, and 9#.

6 Conclusion

As urbanization expands and city buildings increase, urban buildings are increasingly affected by environmental vibrations [8]. This article focuses on testing and evaluating vibrations from excavation support pile construction near high-rise residential buildings. It introduces testing methods for environmental vibrations, obtaining peak velocity values and corresponding vibration frequencies at measurement points using vibration testing instruments. Results are evaluated per China's "Code for Acceptance of Construction Quality of Building Vibration" (GB50868-2013). Test results indicate low safety risk from vibrations induced by excavation support pile construction near Building 10#. Conclusions from Building 10#'s vibration tests can guide safety assessments for other nearby buildings in the residential complex. These testing and evaluation methods offer valuable insights and references for similar projects.

References

1. Shen Y, Zheng JG, Chen LZ. Research on Evaluation Indicators of Environmental Vibration Effects on Engineering Structures[J]. Earthquake Resistant Engineering and Retrofitting. 2010, 32(5), p1-7.
2. Xu J. Handbook of Building Vibration Engineering [M]. Beijing: China Architecture & Building Press, 2002.
3. Liu YZ. Environmental vibration response and long-term settlement prediction induced by metro operation in Jinan area [D]. Shandong Jianzhu University, 2023.
4. Wu D, Gu X, Liu X. Study on vibration measurement and prediction models induced by Shanghai metro operations in soft soil sites[J]. Structural Engineer, 2023;39(05):174-183.
5. Guo JX, Wei XB. Key Technologies for Safety Inspection and Evaluation of Structural Integrity of a Factory Building under Vibration Conditions[J]. Engineering Quality. 2024;42(05):55-58.
6. GB 50868-2013, Code for acceptance of constructional quality of building vibration, 2013.
7. GB 10071-88, Methods for measuring environmental vibration in urban areas, 1988.

8. Zhou DH. Experimental study on environmental vibration characteristics of an underground urban rapid transit line at 160 km/h[J/OL]. Railway Standard Design. 2024, 1-8.