On-line Monitoring and Data Analysis of Environmental Vibration of High Concrete Dam

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Abstract. As we all know, our country has actually gradually developed into a country with frequent occurrence of global earthquakes. The global earthquakes in the southwest region are the most serious. The most severe earthquake occurred in parts of the southwest. In short, the seismic performance design of a high dam is reflected under the action of the high dam for a given amount of seismic motion and input load. At present, one of the main technical methods for studying high dam seismic engineering is to use model calculations and experiments on its structural dynamics. Moreover, the earliest dam prototype dynamic experiments in my country only occurred in the 1970s and 1980s, and few people in China conducted experiments on these dams. Although there were already a certain degree of practical results at that time, a batch of valuable materials was obtained. However, no matter from the perspective of safety or the actual effect on vibration, as well as the prototype dynamic measurement and test method of the above-mentioned main dam, it has not been well applied to the current expressway. Therefore, it is necessary to consider finding an alternative original kinetic test method. The purpose of this article is to in-depth study the data analysis and application of the online monitoring system of environmental vibration of reinforced concrete high dams in my country. A new online monitoring system for dam environmental vibration is carried out for simulation experiments. Experimental research shows that the noise frequency of the three detection points of environmental noise and vibration monitoring is basically controlled between 1.5~2.0 hz, while the noise frequency of the detection point of the symmetrical location is relatively close.

Keywords: Environmental Vibration, Online Monitoring, Data Analysis, Acquisition Subsystem.

1. Introduction
The comprehensive evaluation of the overall performance of seismic design and safety of high dams is based on the essence of engineering technology, that is, on the basis of basically establishing the overall performance evaluation goals set by the state [1, 2]. A performance systematic evaluation project for comprehensive evaluation, optimization and analysis of the overall performance of high dam construction engineering safety and macroeconomic benefit indicators [3, 4]. However, due to the time randomness of large dam earthquakes, the natural destructiveness of the structure may be severely damaged, the time extension process and the high-strength nonlinearity, the constitutive relationship between the concrete body and the main building material, etc. The seismic grade design of high dams is still at the level of semi-scientific experience and semi-technical theory [5, 6]. These
design theories and guidelines have been combined with engineering practice for a long time, and have played a great guiding role in my country's water engineering construction [7, 8].

When multiple vibration sources are input jointly, the mutual influence between systems produces more interference factors (such as noise). These interference factors are superimposed on each other, so that when the traditional transfer function is used for prediction, the vibration caused by non-vibration sources is amplified, and the prediction results the actual results are quite different [9]. The orifice vibration signal is used as a single input, and the accuracy of the predicted site vibration spectrum characteristics has been improved, but the vibration amplitude is obviously too large, and the predicted deviation is mainly affected by factors such as noise [10].

In this paper, a set of environmental turbulence test monitoring and processing system for dam engineering is designed based on the test of environmental vibration. The main functions of the system include three core subsystems: data collection, wireless data transmission, mass data collection and storage, and information processing. In each process, they have personally experienced the preliminary technical preparation and implementation work such as the early stage, the system structure design, the design and selection of instruments and equipment, and the laboratory's wireless networking network test work. On this basis, the system the overall structural design of the company has been optimized again and again and major technical improvements have been made. Afterwards, real-time monitoring of internal environmental temperature vibration is carried out on the main structural position of the dam and the internal building temperature of each structural section. Finally, comprehensively analyze the large amount of data obtained from the monitoring results, using time domain analysis, frequency domain analysis, modal analysis and other techniques to obtain structural dynamic characteristics, and obtain certain conclusions and results.

2. Online Monitoring of Environmental Vibration of High Concrete Dam

2.1 Research Methods

2.1.1. Literature research method. Consult the documents closely related to the construction of "concrete high dam", take a series of conceptual data such as "environmental vibration" and "online monitoring" as the main elements, and conduct comprehensive research and analysis on domestic and foreign related documents. By comparing, analyzing and generalizing with related literature, we can understand the dynamic status of environmental vibration monitoring of concrete high dams at this stage, which provides a theoretical basis for the research of this paper and ensures the feasibility of this research.

2.1.2. Quantitative analysis method. Qualitative analysis is related to quantitative analysis. Quantitative analysis refers to the analysis of mathematical hypothesis determination, data collection, analysis and testing.

Qualitative analysis refers to the process of conducting research through research and bibliographic analysis based on subjective understanding and qualitative analysis.

2.1.3. Inductive and deductive method. Through the analysis of relevant theoretical research in domestic and foreign academic circles and the development of environmental vibration monitoring systems in reality, summarize the development status of environmental vibration tests in the emerging stage and the changes in environmental vibration monitoring systems.

2.2 Performance-Based Seismic Design of Structures

2.2.1. Rigid design. The easiest way to prevent buildings from being damaged in an earthquake is to increase the rigidity of the structure. The period and the foundation are called a rigid whole. However,
this approach is neither economical nor useful. As the structure height, span, and complexity increase, it is also unrealistic to take such measures.

2.2.2. Flexible design. Contrary to the rigid structure system, the design idea of the flexible structure system is to reduce the mechanical stiffness of the structure as much as possible. Although this can effectively reduce and increase the seismic load and strength acting on the building structure, under some relatively large seismic stress conditions, it will directly cause the damage or collapse of the building due to deformation or serious damage. Under the action of small earthquakes and other conventional loads, it may be difficult to fully meet the normal operation and use requirements of the building because the stiffness is too low.

2.2.3. Ductility design. Ductile design is currently a more common design concept, but in recent years, with the continuous development of social economy, the idea of ductile design has begun to be challenged. On the one hand, the complexity of the building structure continues to increase, and the repair work after the earthquake is expensive and takes a long time, resulting in huge indirect economic losses after the earthquake. This is not allowed for certain buildings that cannot be interrupted in use. On the other hand, the safety and importance of the internal facilities of certain structures far exceeds the building itself (such as nuclear power plants). Once this structure cracks in an earthquake or even undergoes excessive deformation, the huge losses will be Unacceptable to society.

2.2.4. Structural control design. The structural control design breaks through the previous design idea of resisting earthquake disasters by adjusting the stiffness of the structural members themselves, and introduces control mechanisms (such as various seismic isolation devices and energy-consuming devices) into the building. However, there are still some problems in the actual application of control structures in large-scale civil engineering: First, control measures that rely on external energy sources are often unreliable during earthquakes. Secondly, although the active control measures have good adaptability, because the quality of the structure itself is very large, the external energy required is very large, which is difficult to guarantee when the actual disaster occurs.

2.2.5. Performance-based seismic design. In the field of earthquake-resistant buildings, it is generally believed that the seismic fortification of structures must be developed from only focusing on structural safety in the past to focusing on the comprehensive development of structural efficiency, safety and economy. It is necessary to consider the existing seismic planning concepts and methods in terms of performance, and put forward seismic performance planning on this basis.

2.3 Vibration Detection and Acquisition Subsystem
Vibration phenomenon detection and data collection vibration monitoring platform subsystem is mainly composed of sensors, digital collectors, GPS templates, UPS power supplies, POE templates, etc., as shown in Figure 1. The main purpose of this kind of vibration sensor is to refer to the 941b ultra-low frequency vibration meter. The measurement function of the low frequency vibration meter is mainly to convert the physical voltage measurement value of a vibration signal at the location where the signal to be measured is to be sent into a the vibration voltage measurement value of the analog signal is measured by the x, y, z three two-by-two connected or erected nodes. The digital data acquisition instrument is mainly used to undertake the conversion of digital a/d data conversion and other digital data acquisition, as well as the digital packaging and data transmission of collected data.
2.4 Research on the Online Monitoring Algorithm of High Concrete Dam Environment

In order to accurately obtain the instantaneous response frequency and instantaneous response amplitude of various measured instantaneous response analytical signals, this article attempts to use the relationship between the instantaneous real part of the instantaneous analytical reaction signal and the positive and complementary sine waves of the imaginary part to accurately define the instantaneous response frequency. And the instantaneous response amplitude. However, such a signal processing method can only be used for single- or dual-component frequency signals. For multi- or dual-component frequency signals obtained in actual frequency measurement, it must be decomposed by using appropriate processing methods to become a combination of multiple single or dual component frequency signals.

Let $o(p)$ represent the signal to be decomposed, EMD decomposition processes the signal through a process called "screening":

First find out all the maximum points on $o(p)$ and connect them with cubic splines to form the upper envelope of the signal. Similarly, the lower envelope of the signal can be obtained. The average value of the upper and lower envelopes is recorded for. The difference between $o(p)$ and is defined as:

$$f_{11} = o(p) - l_1(p)$$

$$w_1(p) = o(p) - B_1(p)$$

After the above steps, $o(p)$ can be decomposed into the sum of n IMF components and margin $w_n(p)$:

$$o(p) = \sum_{j=1}^{n} B_j(p) + w_n(p)$$

**Figure 1.** The composition of the vibration detection and acquisition subsystem
3. Experimental Research on Online Monitoring of Environmental Vibration of High Concrete Dam

3.1 GPS template test
Place the GPS near a window sill and other open-air locations, and connect it to digital media. Observe how long it takes for GPS to work properly and send time and latitude information. After a long time of testing, it is found that about 20 GPS cold starts are required. Clear all historical information and restart. Because there is no previous information, it takes 3~5S for hot start and hot start, which is in line with GPS parameters and also Meet the monitoring requirements.

3.2 Test of digital acquisition instrument
The digital acquisition method is the key to the entire system, so it must be tested more rigorously. This article uses a fully numerically controlled dual-channel arbitrary waveform signal transmitter (as shown in Figure 2) to compare the signals before and after acquisition. We can use digital The acquisition method tests the accuracy of the sampling. After a period of testing, five acquisition methods are used to test the timing and adjustment of the sampling. Increase channels, restart the acquisition medium, etc. The results are normal, and 20 high-precision digital acquisition methods should be selected. And normal operation as the final collection method of the network.

![Figure 2. Full CNC dual-channel arbitrary waveform signal transmitter](image)

4. Online Monitoring Experiment and Data Analysis of Environmental Vibration of High Concrete Dam
The time-domain characteristic quantity analysis of the signal is a more intuitive way to characterize the signal characteristic. The quantities that can be statistically analyzed include the maximum value (minimum value), mean value, and mean square deviation.

Take the maximum value as an example. Because the collected data is a discrete amount of voltage, it is necessary to inversely calculate the final speed value through the sensitivity of the vibration pickup. The results of the simulation experiment show that the maximum value of the velocity in the three directions at each measuring point is shown in Figure 3.
Figure 3. Maximum speed of each measuring point in three directions

Table 1. Vibration frequency and damping ratio of each measuring point

| Measuring point number | Natural frequency(Hz) | Damping ratio(%) |
|-----------------------|-----------------------|------------------|
| 1                     | 1.5625                | 1.97             |
| 2                     | 1.8555                | 1.73             |
| 3                     | 1.7578                | 1.79             |

It can be seen from Table 1 that the vibration frequencies of the three measuring points are basically in the range of 1.5 to 2.0 Hz, while the vibration frequencies of the measuring points at the symmetrical position are close.

5. Conclusions
This paper proposes a method to obtain the vibration characteristics of high concrete dams by using environmental vibration. First, based on the above ideas, a set of online monitoring system for dam environmental vibration was designed. It mainly includes three parts: vibration detection and data collection, data wireless transmission, and data storage and analysis. On this basis, equipment selection, laboratory testing, software writing, etc. were carried out. Finally, networking experiments were carried out in the laboratory, and initial results were obtained. Although the environmental vibration method has many advantages, the structural response it can cause is very limited, so only lower-order structural dynamic characteristics can be obtained.

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