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The Earthquake Monitoring System for Dams of a reservoir in China

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SUMMARY

In this paper, the authors give a brief introduction to the earthquake monitoring system newly developed for two dams of a reservoir in North China. The two embankment dams are 66, 56 meters high and 960, 1008 meters long respectively. One of the dams suffered from severe landslide because of the 1976 Tangshan Earthquake, the design PGA of this site is set to 0.25g. Because of the complexity, it is quite difficult to predict the dam earthquake response by numerical simulation, thus the recorded motion data will be very useful for the dam dynamic design and seismic safety assessment. In order to monitor the earthquake response of the two dams, two unique sets of new type earthquake monitoring system are developed and installed in February 2003. Each of the system consists of a Data Logger (16 bit resolution, synchronous 18 channels) and 16 Force Balanced Accelerometers (0-50Hz, 120 dB). Accelerometers are installed at the bottom, middle as well as the top of the dams. Two gears of sensitivity are set for the accelerometers; one is for strong motion recording and the other for microtremor measurement. The microtremor data can be used for seismic safety evaluation of the dams.

Key words: embankment dams, earthquake response, central recoding data logging system, health monitoring

INTRODUCTION

Earthquake is an occasionally occurred disaster with great damage. For an important structure, the owner and the designer take great concern about the structure safety during and after an earthquake. Structural engineers can use the earthquake records to check the response analysis and recognize the local ground motion characteristics.

During the past century, accelerographs have been proven to an effective instrument for structure safety evaluation and profound understanding of structure dynamic response during an earthquake. Accelerographs can also be used for earthquake alerting. Y. NAKAMURA (1988) developed UrEDAS for urgent earthquake detection and alarm. ESPINOSA-ARANDA etc. (1996) developed earthquake early warning system for Mexico City. Since the great progress in electronics and communication during the past decades, modern accelerographs become much more powerful than before. Here a new developed earthquake monitoring system used for a twin dams is introduced. Comparing the traditional one, this system takes a lot of advantages as multi-channel, control data and real time event data can be transmitted through convenient communication ways (direct connection, modem and Internet).

Configuration of the earthquake monitoring system

The new developed earthquake monitoring system is mainly consisted of three parts as illustrated in Figure 1. The first part is Accelerometers, which connect to the second part, i.e. Data Logger via cable; the third part is control, analysis and communication software.

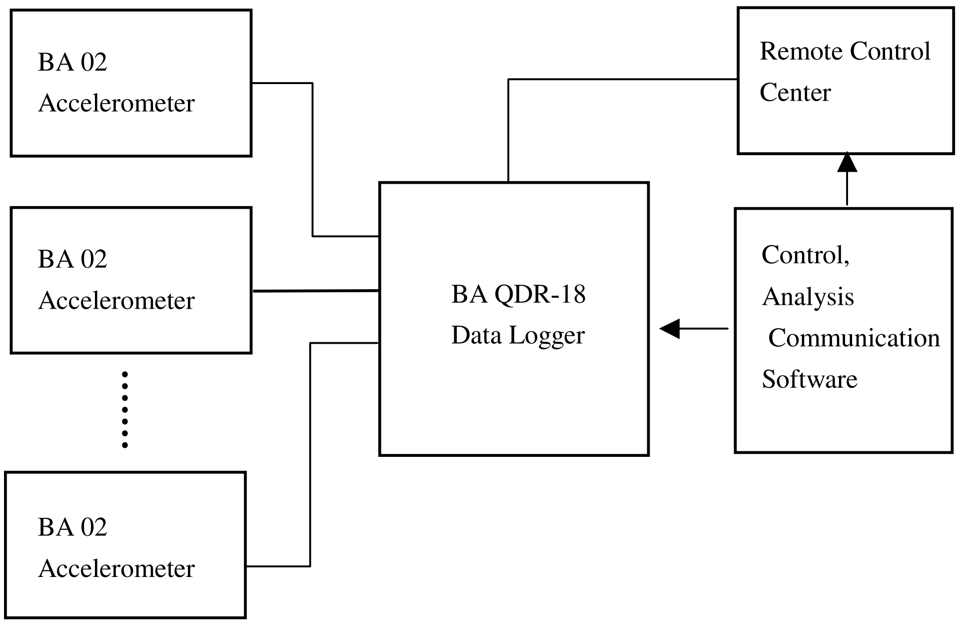

Figure 1 Configuration of the new developed earthquake monitoring system

Sensors

The first part in Figure 1 is Force Balanced Accelerometer with model BA 02. The specification of BA 02 is listed in Table 1.

Table 1 Specification of BA 02 Accelerometer

Full Scale Range	± 2.0 g, ± 0.2 g
Frequency Range	0~70 Hz
Damping	0.7 critical
Dynamic Range	120 dB from 0 to 70 Hz
Noise	Less than 3 μ V from 0 to 50 Hz
Cross-axis	3%g/g
Linearity	0.5%
Power	± 12V DC, 3.1 mA per axis
Operating Temperature	-25° to 70° V

Recent years, microtremor records are used to evaluate health situation of important structures. In order to monitoring both natural earthquake and microtremor, two levels of sensitivity are designed in BA 02 accelerometer. The low sensitivity is used for natural earthquake and the high sensitivity for microtremor. The sensitivity converting can be easily done by a switch installed on the specially designed Connecting Bridge, which also provides power supply for BA 02 sensors.

Data Logger

The second part in Figure 1 is 18 channels Data Logger with model BA QDR-18. Two sets of BA QDR-18 are used for the twin dams. 18 independent A/Ds ensure simultaneous sampling without channel screw. The specification and principle of BA QDR-18 is listed in Table 2 and illustrated in Figure 2 respectively.

Three kinds of communication are employed in BA QDR-18, i.e. direct connection, modem and Internet.

Table 2 Specification of BA QDR-18

Sensor channels	18	Dynamic range	＞90 dB
Resolution	16 bits	A/D time delay	＜5 ns
Channel skew	none	Input level	±5 V
Communication Baud rate	4800~ 115.2	Sampling rate	20, 50, 100, 200, 500, 1000 Hz
Trigger	Mouse, level setting, STA/LTA	Memory	64M~20G
GPS time	1 ms	Communication	Cable, Optical fiber, Modem, TCP/IP, 422
Windows based Software	Configuration, Sampling, Browsing, Saving, Analyzing, Remote alerting capability	Power consumption	200mA@12V

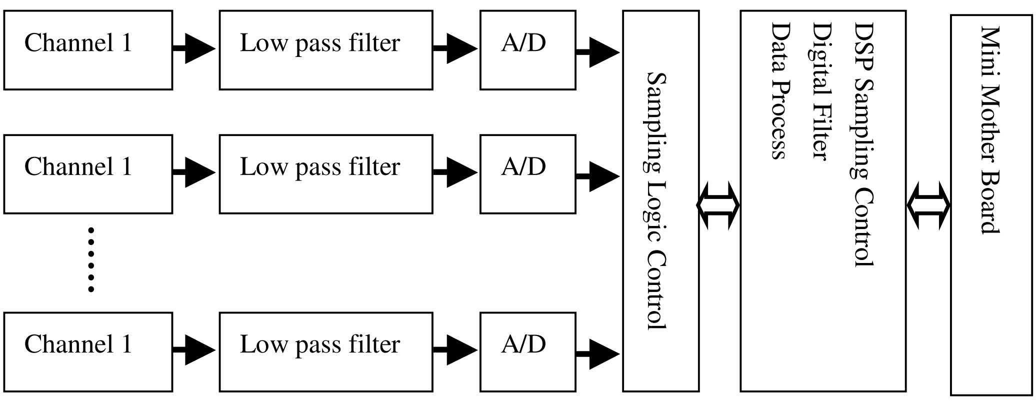

Figure 2 Schematic diagram of BA QDR-18 Data Logger

Monitoring software

Software is compiled for the new earthquake monitoring system. The software is consisted of three function blocks as hardware control, data process and communication. Thus real time data logging, waveform browsing, events requiring, system configuration and modifying,

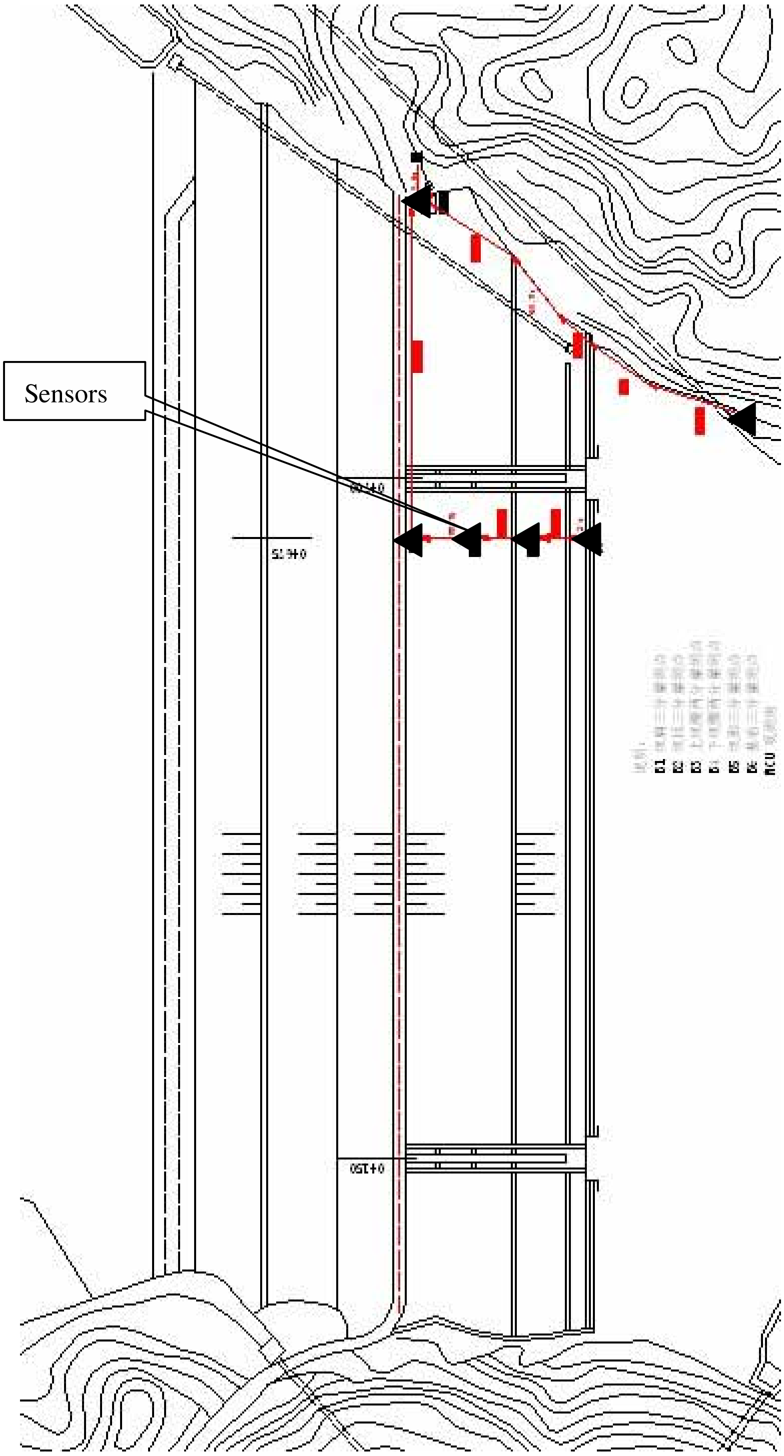

Figure 3 Sensors arrangement on one of the twin dams

earthquake events identifying, trigger judging, earthquake alarming, accelerogram baseline adjusting, digital filtering, integrating, FFT and response spectrum analyzing can been done.

Instrumentation on the twin dams

The distance between the twin dams is 8 kilometers away. Both of them are embankment dams. One of them is 66 meters high and 960 meters long (as shown in Figure 3); the other is 56 meters high and 1008 meters long. The later one suffered some damage during the 1976 Tangshan Earthquake.

The criterion for sensors arrangement is to grasper the integral vibration by least sensors. Thus 5 points in one cross section for each dam are selected for sensors installing as illustrated in Figure 3 and Figure 4. Two sets of 3 orthogonal sensors are installed on the top and base of one of the dams respectively, and two sets of 2 horizontal sensors are installed between top and base. In order to monitoring the vibration without the dam effect, one set of 3 orthogonal sensors is installed on rock site two times of the dam height away from the dam base.

Conclusion remarks

Comparing with the traditional accelerograph, the new developed earthquake monitoring system is much more advanced. The sensors used here are designed with two levels of sensitivity for monitoring both natural earthquake and microtremor. A switch installed on the connecting bridge can do the sensitivity converting, thus sensitivity can be adjusted in the control room instead of sensor casing in field. Control data and event data can be transmitted real time through direct connection, modem and Internet.

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