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DETECTING INFRASOUND EMISSION OF DEBRIS FLOW FOR WARNING PURPOSES

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ABSTRACT

There is an infrasonic sound wave emitted through the air when a debris flow is formed and moves in the source area. As inaudible sound (less than 20 Hz of frequency), infrasound can propagate around a sound source through atmosphere. The velocity of an infrasonic wave is about the same as of that audible sound, about 344 m/s at 20°C, though it is faster than the velocity of debris flow, usually 5-20 m/s. Fortunately the signal of infrasound can move for long distances. Therefore, it is possible to develop a device for warning the debris flow, which is coming up. The infrasonic debris flow observation system has been built in the Jiangjia Ravine, Dongchuan City, Yunnan Province. Data obtained and analyzed over there included the pressure of signal, about 0.5-4 Pa and the predominant frequency, 5-10 Hz. Based on such data, we have developed a debris flow warning device, DFW-I Model. The device proved successful through experiments and calibrations for many years. It can alert the arrival far away above more than10 min in advance.

Key words: debris flow, infrasonic behavior, warning device

INTRODUCTION

Debris flows cause loss in property and life for people all over the world. Researchers have developed various warning devices to alert residents, who live in dangerous area. These devices should be capable to avoid loss of life if they could detect the arrival of a debris flow some minutes in advance. The warning devices developed so far by researchers detect an occurring debris flow with contact or noncontact devices. Because of problems regarding the devices and environment conditions errors occurred frequently.

According to practical experiences and measurements we know that there is a certain infrasonic component in the sound emitted by the formation and movement of a debris flow. This signal will travel long distances through the atmosphere with very small dissipation. Therefore we have a possibility to detect the occurrence and movement of a debris flow from its source location and issue a warning for local residents.

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We have been trying to carry out the development work for 10 year. The key part of the device is the acoustic sensor: the CHZ-Model of capacity microphone, developed by Acoustics Institute, Chinese Academy of Sciences (CAS). The lowest frequency limit of this sensor is about 3 Hz. It is effective to detect infrasonic signals emitted by debris flow. Since 1995, the experiments have been executed in Jiangjia Ravine, Dongchuan City, Yunnan Province. No error occurred and debris flow were detected more than 10 minutes in advance (sometime more than half-hour). This confirms that this device is reliable.

INFRASONIC BEHAVIORS OF DEBRIS FLOW

It is well known that a debris flow produces vibration when it moves along a channel (Zhang 1993). The vibration then produces sound wave. The sound wave usually contains audible sound with a frequency of from 20 Hz – 20 kHz and inaudible sound of frequencies less than 20 Hz. The inaudible sound is named infrasonic sound. It is usually produced by natural disasters, for example, volcanoes, earthquakes, magnetic storms, tornadoes, typhoon, rockfall, avalanche, and landslide, etc (Cook, 1962). Infrasound can be artificially produced by explosions (nuclear bomb specially) and by industrial noise (pile machine etc).
The debris flow is a dense two phase (water and sediment) fluid. A lot of boulders, big tree, and frames of construction can be found in the fluid. The sound resembles thunder and can be transported for a few kilometers. The geosound sensors can be used to detect this signal (Zhang, 1993, Itakura et al, 1997). We found that there are two peaks in the signal spectrum, i.e., at about 10 Hz and about 50 Hz of predominant frequency (Zhang, 1993) from which we deduce that there is a certain amount of lower frequency during sound emision of debris flow.
The infrasonic sensor is used to receive very small oscillation from the atmosphere because of infrasound propagation. The early infrasonic device has bulky and complex construction. Since 1970's the Acoustics Institute, CAS has been developing a capacitive sensor of smaller volume, high sensitively (the highest is about 100 mv/pa), wide frequency responds (3 Hz-100 kHz), and wide dynamic range (the widest is 180 dB). This sensor is in accord with International Acoustics Standard. So it is chosen to measure infrasonic emissions of debris flow. Certainly we are interested in this lower part of the frequency range. Each sensor is calibrated strictly.

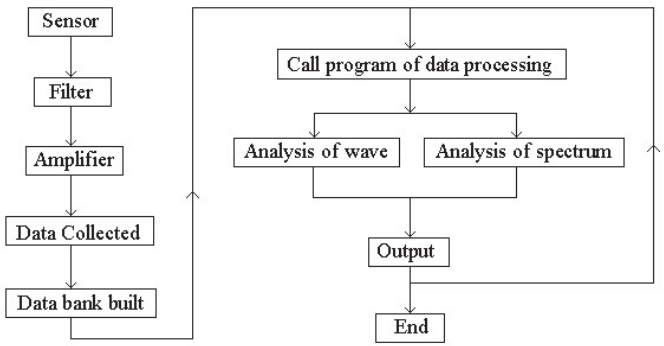

Fig. 1: Flow Chart of Collection and Processing System of Infrasonic signal of debris Flow

The infrasonic observation system for debris flow has been installed in the Jiangjia Ravine. The flow chart of this system is shown in Fig. 1. The filter of system cuts the signal with a frequency greater than 20 Hz (i.e., frequencies less than 20 Hz is accepted by this system). Adam 5510 Collector (or any data collectors) executes the data collecting. The frequency of data collecting is 60 Hz. Every 30 seconds a file is recorded. Then according to the random analysis principle we have developed a special program to process the data collected in the files. The processing program can do wave analysis, statistical analysis and spectrum analysis. Because the infrasonic signal can pass though a very small fissure, the system can be set indoors. Fig. 2 is a typical wave and spectrum graphs of debris flow infrasound. Fig. 2 shows that the wave of infrasonic signal resembles a sine wave. Its amplitude can be calculated by sensitivity of the sensor. Obviously, the energy of the debris flow, i.e., determines the amplitude of signal. We think that the greater are the discharge and the density of a debris flow, the higher is the amplitude of the signal. The predominant frequency appears in Fig. 2. The predominant frequency varies with the magnitude and behavior as well. It will change to the lower range of the spectrum when debris flow has a big discharge and contains many boulders. From the analysis of the data collected in Jiangjia Ravine the infrasonic sound pressure is about 0.5-4 Pa and predominant frequency about 5-10 Hz.

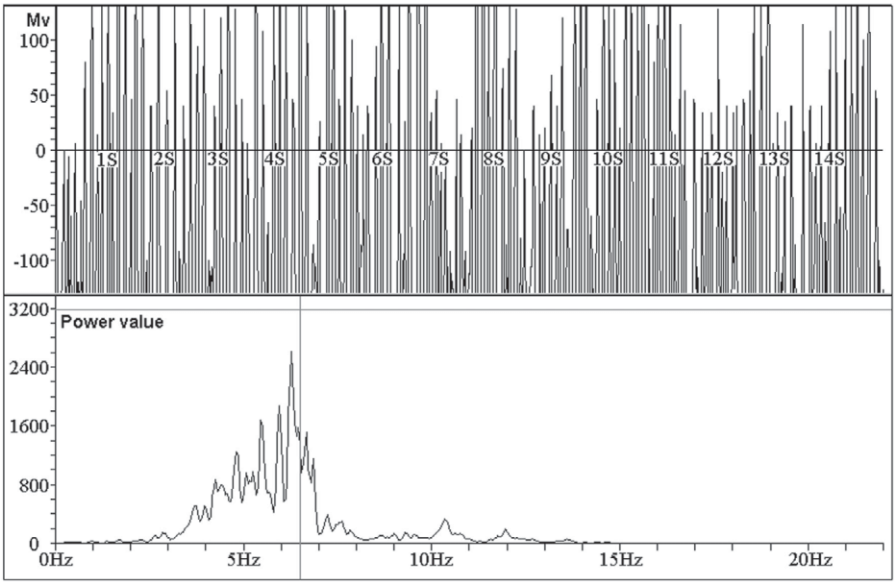

Fig. 2: The Graph of Infrasonic Wave and Spectrum of Debris Flow

We have also collected background data in the debris flow district, regarding for example, thunder, strong wind, and ocean wave as far as natural phenomena, and also airplane noise, resonance produced by grade separation bridges, and pile machine from industrial noise as far as manmade noise is collected. They are useful to develop warning device.

INFRASONIC WARNING DEVICE OF DEBRIS FLOW

Infrasonic Warning Device of Debris flow of DFW-I Model

The infrasonic wave has the same velocity of audible sound that is 344 m/s at 20ºC. This velocity is greater than debris flow velocity (the greatest speed is about 15-20 m/s usually). Therefore we have the possibility to catch the information of debris flow occurring far away at its source point and have enough time to issue a warning in advance. The diagram of the warning device, DFW-I Model is shown in Fig. 3. When sensor of CHZ receives infrasonic signal the processed data will have two output channels. The first is devoted to the collection of data for specialist and interested user. The second is devoted to alert people by sound and light. Obviously the two channels can be used contemporaneously. The device has been set indoors. Common AA-Battery provides electric supply. The device can stop its warning sound if the users don't need it any more. So to operate this device is very simple. The users operate it according to the manual instruction only and don't need any special training.

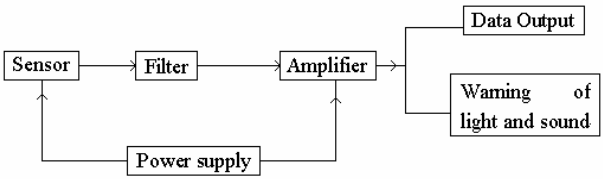

Fig. 3: The Diagram of Infrasonic Warning Device of Debris Flow

Application Cases

Since 1995, the watershed of Jiangjia Ravine has been chosen for experiments. More than 10 event of debris flow occurred each year (Zhang, 1993). The device did not make any error for many event of debris flow during the experiment years. The detected debris flow occurred more than 10 minute in advance. Some cases are as following:

Case 1: At 23:00, August 8th, 1995 the rainfall occurred in the upper part of the watershed. The warning device was set for waiting condition. The device issued a warning information at 0:15, August 9th, 1995 and stopped at 0:30 am. At that time the rain stopped. In the morning of August 9th, we investigated to the upper basin along the galley and found that the debris flow did occur in the preceding night. It is about 6 kilometer upstream of the site.

Case 2: At 17:55, August 10th, 1996 the device started the recording when rainfall began. The device issued a warning information (sound and light) at 22.45. The debris flow arrived at the device site at 22:59. The warning was given 14 min in advance.

Case 3: At 14:20, July 28th, 2000, when the rainfall appeared in the upper watershed the device was started. The device issued a warning in 16:36. The warning signal was weaker in 17:20 when upper watershed was clearing up and stopped at 17:30 when it was sunny. We went into the galley and met debris flow about 7 km from device site as well.

Case 4: At 17:30, August 9th, 2000, the rainfall with thunders appeared in the upstream of the watershed. The device issued a warning signal at 17:32. Debris flow reached the device site at 17:56. The 24 minute warning came.

Case 5: At 16:57, August 5th, 2001, the device issued a warning signal. The debris flow came to device site at 17:28. The 31minute warning was given.

Comparison with other types of warning devices

At present there are two types of warning devices. They can be divided into contact devices and noncontact. The contact type of warning device is named cutwire type. It consists of a metal wire that crosses the channel and is cut by the debris flow passage. The signal of the wire cut will start warning device. As is well known the debris flow passage causes erosion and deposition along the channel. So this method may produce false information. To get a warning early enough in advance the wire needs to be placed in middle catchment. In this case the metal wire is damageable for human activities and natural reasons. Another problem is how to transport the signal downstream. The noncontact method is the geosound-warning device we developed in 1980's. A sensor of piezoelectric ceramic is inserted into the earth's crust near a debris flow prone channel. This sensor can receive the signal from geosound wave when debris flow impacts the earth's crust. Our research has shown that the predominant frequency of geosound wave of debris flow is 30-80 Hz, about 50 Hz usually (Zhang, 1993). Investigations have revealed that the signal of geosound waves decreases quickly. So the sensor has to be set in upper part of watershed to assure warning enough time in advance. Emitting and receiving devices are necessary for warning systems. The sensor and the emitting device are set in upper part of watershed and work in field condition for long time. They are damageable by human and natural causes. In addition there is also a problem about electric supply. Therefore this method has obvious drawback.
The infrasonic warning device of DFW-I Model has obvious advantage compared with the above. It is a warning device of new concept and utilizes up to date methods. DFW-I Model is very simple in construction. The sensor has the size of a coin and the weight of 9 grams only. The sensor cannot miss any infrasound from a debris flow. Because the direct current is used for this device it can be free from the influence and disturbances from the electric net. Of course this device can not be injured by human and natural reasons because it is set indoors about 10-15 kilometer from the source of debris flow (in the case of Jiangjia Ravine).

Application prospect

DFW-I Model will be used not only to mitigate debris flow hazard but also in other fields. This sensor can be used for other disasters, for example, avalanche, landslide (rock fall specially), dambreak of lakes and reservoirs, and fall of mine wall, etc, all these will produce infrasound signal as well.

CONCLUSION

Infrasonic sound is emitted by the passage of debris flows. The signal possesses a predominant frequency and enough sound pressure. It can be detected and recorded for warning and for research work. Furthermore other natural disasters and phenomena produce the infrasonic signal as well. Thus it is needed to distinguish them from debris flow before.

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