GeoWatch

GeoSys

geophysical measuring solutions

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GeoSys' Contribution to Dam Safety

It is important to point out the position of the engineers carrying the responsibility for the planning, realisation and maintenance of dams. Today's environmentally conscious society is becoming increasingly critical of many of the large technical challenges we are confronted with. This has lead to increasingly stringent specifications, rules and regulations which must be adhered to when planning and realising such a project. Taking part in complex technical projects and carrying the responsibility for their safety is therefore only possible by having a deep understanding and broad knowledge of the many different sciences involved in the task.

To be able to take this huge responsibility in a time of rapidly developing expertise, it is necessary to bring together specialist for the task. Each specialist needs to have the best knowledge in his particular field, and must also be able to work together with other specialist to be able to understand all of the projects requirements. In the complex task of safety considerations related to dams, GeoSys is the specialist in the earthquake instrumentation field.

Based on different objectives of a dam instrumentation, and different types of dam structures, the earthquake instrumentation solution can vary significantly from dam to dam. A simple solution may be a single strong motion recorder on the crest of a small earth dam, to determine the peak acceleration of an earthquake. An other approach may be a complex seismic network with several measuring points located at different sites within an arch dam. Such an instrumentation gathers data on the earthquake behaviour of dams and on the motions they are subjected to. The analysis of this data helps scientists to develop sophisticated consolidated models which describe major phenomena and effects which influence the dam safety.

This issue of the GeoWatch helps the dam safety specialists in getting a base understanding about the different earthquake instrumentation solutions available.
GeoSys, as specialist in this field, has the solution for your application!

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The need for strong-motion instrumentation of dams is identified and instrumentation schemes are proposed accordingly. The instruments used for dam monitoring have changed drastically in the last few years. Analog recording now belongs to the past. The new digital generation of accelerometers is more versatile and reliable. The stations of seismic arrays can be easily interconnected so that all instruments record in a synchronised fashion. The aim of this article is to present a brief overview about the different techniques used in such arrays.

Hp. Boller, GeoSys AG

Strong Motion Instrumentation Array in Dams

Several different systems for dam monitoring are used. The simplest is one independent accelerometer on the crest of a dam, the most extensive is a complete network with accelero meters located from the base up to the crest of the dam and one free-field station nearby. The instrumentation scheme used depends on the type of dam and its surroundings, on the regulations and on the task of the monitoring (scientific or engineering).

A typical scheme for an arch dam is proposed in figure 1. Two accelerometers are placed on the crest, one on the left abutment and one on the bottom of the dam. A fifth accelerometer is installed to observe a reference free-field motion which is not affected by the presence of the dam.

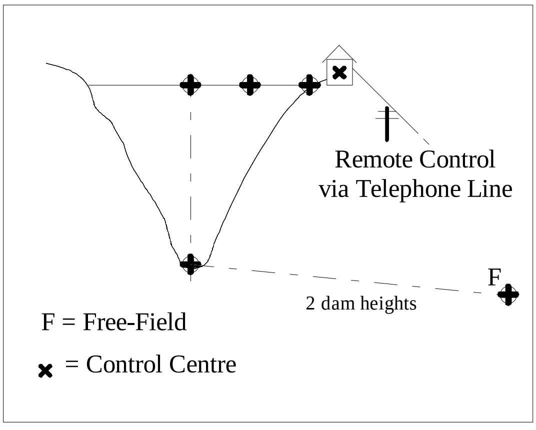


Figure 1

Figure 2 shows a typical scheme for the instrumentation of a gravity dam. One accelerometer is located on the crest and two are located in the base of the dam. A forth instrument is installed to observe the free-field motion.

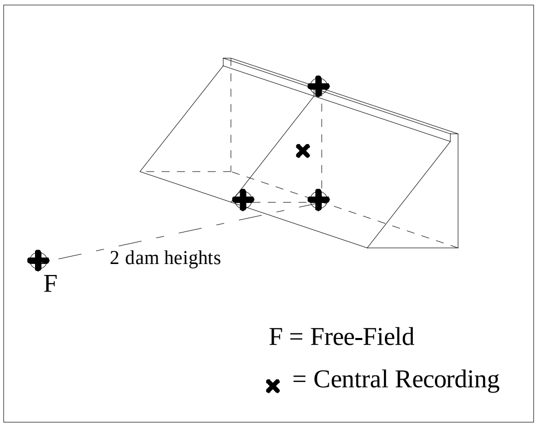


Figure 2

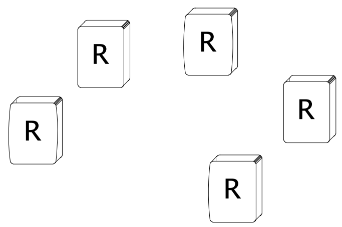
Studies on effective input motion and wave propagation require that all instruments in an array record in a synchronised fashion. Interconnection of each recorder unit with enforcement of common trigger and common sampling is therefore indispensable.

When interconnecting the instruments, care must be taken to minimise possibilities for malfunctions and damages due to differences in electric potential between the individual units and due to lightning striking in the vicinity of the interconnection cables. Therefore an extensive lightning protection and a proper installation is needed with every station in the array. The use of optical cables for interconnection can be recommended in exposed arrays, even its installation is costly and sometimes problematic.

If the locations of the accelerometers are settled, the decision has to be taken which type of array shall be realised:

- independent recorders (without interconnection)
- interconnected recorders
- local recording network
- central recording network

a) Independent Recording



R = Recorder

One or several independent accelerometers are placed in the dam. This is the simplest solution for dam monitoring, often reasonable and sufficient, but with some restrictions.

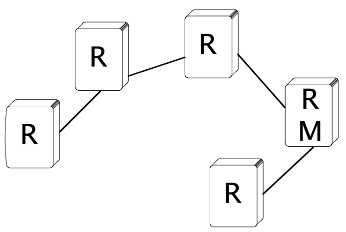
In case of an event each recorder records independently the time history of the event. It isn't possible to make an exact correlation between the individual recordings because there is no common sampling and common triggering available. There isn't any logical connection between the different accelerometers for triggering, therefore false triggering caused by local seismic noise may occur.

To get common time one needs a time source like DCF, Omega or GPS for each recorder. This is often impossible, because the RF signal inside the dam is to poor.

A local output is available for each recorder to activate an alarm. The parameters settings and the data retrieval have to be performed on the site of each recorder.

If several accelerometers are used the reliability of the monitoring is quite high. A malfunction of a recorder affects only one location in the dam. But error- and warning- messages are only visible on the site of each accelerometer, a malfunction won't be recognised immediately.

b) Interconnected Recorders



R = Recorder
RM = Master Recorder

Several independent accelerometers are placed in the dam. They are connected together with two simple telephone cables (2 twisted pairs). This is a favourable solution for many applications in dam monitoring.

Each recorder works and records independently. The data is stored locally in every recorder. The array gives additional common trigger in the simplest form: all interconnected accelerometers will start recording as soon as any selected recorder in the array reaches its trigger level. The drawback of that approach lies in the fact that an accidental trigger (seismic noise generated by construction work nearby, etc.) of a selected recorder causes the whole array to trigger. The internal trigger capability of any recorder can also be disabled, so it starts recording only with external trigger pulse.

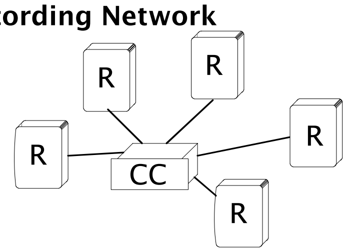
For common time and sampling one instrument of the array (master) is enabled to synchronise and update the internal clock of each accelerometer (slave) via network. A time source like DCF, Omega or GPS connected to the master controls the time system of the whole array and allows therefore easier correlation with recordings made at other arrays or at individual stations.

A local output is available for each recorder to activate an alarm. Because the interconnection is only for trigger, timing and sampling purposes the setting of parameters and data retrieval have to be performed on the site of each recorder.

The reliability of the monitoring network is high. A malfunction of a recorder affects only one location in the array. If a malfunction in the master recorder occurs or the network is interrupted, every other instrument will perform as a stand-alone station, thus recording if the instrument recording trigger level is reached.

The interconnection between the stations can be carried out in ring, star or in net topology. Distances between the stations from up to 2 km are easily realisable.

c) Local Recording Network



R = Recorder
CC = Control Centre

Another solution of a seismic monitoring array can be realised with centralised digital interconnection where a control centre takes control of the whole array. Although centralised recording may be possible, local recording is recommended.

The control centre enforces common trigger only if a logical combination of individual instrument triggers is satisfied. It allows central programming, monitoring and data retrieval of every recorder in the array. To receive an even higher redundancy the data of the recorders can automatically be copied to the optional data storage media (static memory, FLASH-memory, harddisk) at the control centre. The control centre gives online surveillance, common sampling and time synchronisation for the whole array, and as with a simple network, a time source can be connected to the array for synchronising and updating.

An alarm signal can be generated in a way similar to that of recording trigger, thus allowing the dam personnel to be informed immediately on the severity of an earthquake.

A very high reliability results with this type of strong motion array. A malfunction of one recorder affects only one location in the array. If a malfunction in the control centre occurs or the network is interrupted, every local instrument will perform as a stand-alone station.

The status of every station is indicated online on the control centre.

Stations are interconnected in a star topology and interconnection methods available are current loop, RS-232, RS-422, RS-485 and fibre optic. Distances between the control centre and the individual accelerometers of up to 2 km are realisable without additional amplifiers.

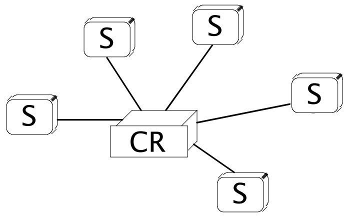
The whole system can be easily accessed via telephone modem.

Radio Linked Local Recording Network
Another possibility to interconnect a local recording network is with radio link, where only two radio frequencies are required. This functions similar to the function of the cabled network above, whereby sampling is synchronised every few seconds by the control centre. Common trigger occurs within one second after first trigger. Common timing, synchronised by time source is also possible.

A malfunction of the telemetry or of the control centre causes the accelerometers to perform as stand-alone stations.

Large distances (up to a few kilometres) between the individual stations and the control centre can be linked without extensive installation of cables, if there is direct sight contact.

d) Central Recording Network



S = Sensor
CR = Central Recorder

The signal of every accelerometer in the network is converted and transmitted continuously to the central recording station. The central recording unit enforces common trigger only if a logical combination of individual station triggers is satisfied. The data are stored on the central recorder data storage media (static memory, FLASH-memory, harddisk). The centre gives online surveillance, common sampling and time synchronisation. A time source can be connected to the array for synchronising and updating.

To obtain better redundancy, it is recommended to have within the central recording station two separate control and data storage units working parallel.

The status of every station is indicated online in the central recorder. The interconnection between the stations is carried out in star topology.

The whole system can be easily accessed via telephone modem.

As you can see, different types of arrays are used for dam monitoring. Table 1 gives an overview over the 4 different systems.

	a	b	c	d
Local Recording	x	x	x	
Central Recording			x [1]	x
Local Trigger	x	x	x [2]	
Logical Array Trigger			x	x
Local Sampling	x	x [2]	x [2]	
Common Sampling		x	x	x
Local Timing	x	x [2]	x [2]	
Common Timing		x	x	x
Local Alarm	x	x	x [1]	
Logical Array Alarm			x	x
Remote Data Transfer			x	x
Remote Parameter Setting			x	x
Centralised Error/Status Info			x	x

1) optional
2) in case of interconnection/control centre/ central recorder failure only.