Ridracoli Dam: surveillance and safety evaluation reported on internet page

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SYNOPSIS. During a period of several seismic events that took place in January 2003 in the valley downstream of the Ridracoli arch gravity dam, inhabitants and local Authorities requested information about the safety conditions of this important structure. To satisfy such an expectation, the Manager of the Romagna Acque, owner of the dam, launched a project aimed at providing such information. Communication through the Internet web was decided and an Internet page was prepared, reporting the safety conditions of the dam, with respect to hydrologic, hydraulic, static and seismic aspects and the resulting surveillance activities.
Methodologies and operative techniques are today mature and available for an effective evaluation and surveillance of dam safety, and for presentation to the resident population living downstream of the dam. Data collected at the Ridracoli dam site by several monitoring systems are in fact automatically processed and interpreted in order to evaluate the different aspects affecting the safety of the dam and the protection of the downstream valley.

The experience gained using automatic monitoring and a knowledge based support system is used to obtain on-line evaluation, explanation and interpretation of dam's behaviour, identifying surveillance activities to manage anomalous trends or to minimize critical situations due to flooding.
All information are summarized and presented on the Internet page. In addition, for the people living in the downstream area, the presentation is available on a video, located at the City Hall.

INTRODUCTION

The selected approach and the methodology takes advantage of the automatic monitoring systems (which encompass hydrologic-hydraulic, static and seismic structural aspects) and of the on-line analysis of structural dam behaviour, compared to theoretical models, in order to identify safety

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anomalies, if any. From these analyses the management of surveillance is defined requiring *ad hoc* inspections, collection and analysis of further information in order to define the safety condition of the dam.
The operational procedures for surveillance management have been evaluated by the National Board Authorities for Dams and by the Protezione Civile (Department of Civil Protection), defining the conditions and the thresholds that could induce alert conditions for the dam and for the downstream valley.

RIDRACOLI DAM

The Ridracoli arch-gravity concrete dam (height 103.5 m and crest length 432 m) closes a very wide U-shaped valley in the Tuscan-Romagna Apennines in Italy. The storage reservoir is intended for water supply to 37 communities in the Forlì and Ravenna Provinces, including the main towns and the San Marino Republic.

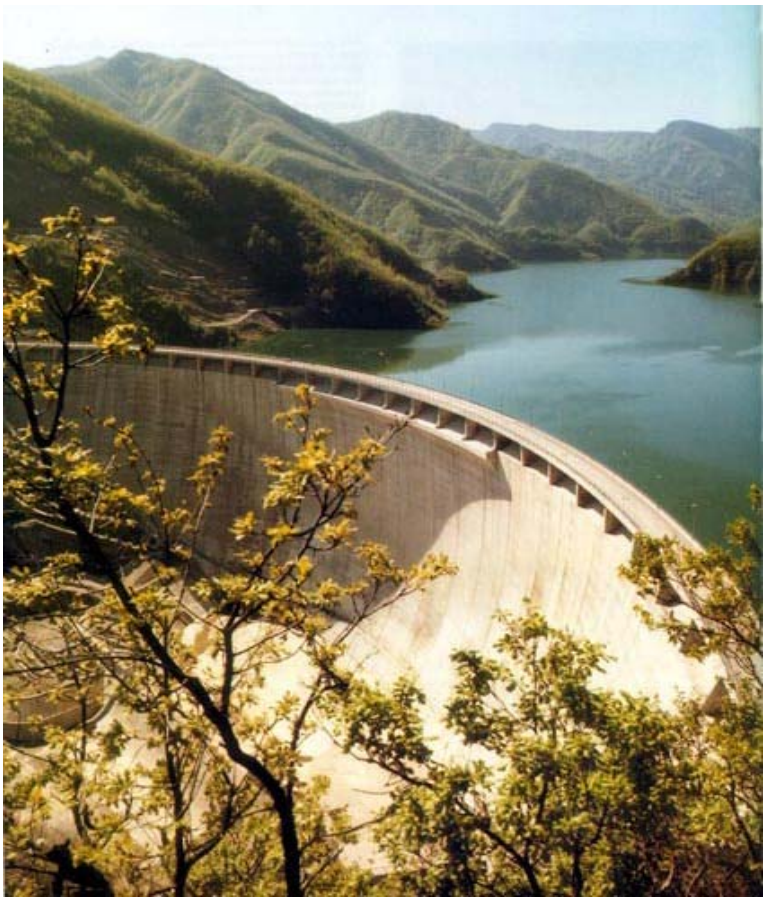

Figure 1: Ridracoli dam

The reservoir was filled completely for the first time in 1986 and nowadays the dam is commissioned for normal operation.

MONITORING SYSTEM

To control the Ridracoli dam site, that is the catchment area, the structure, the foundation, the reservoir banks and the slopes of the downstream rocky formation, a large monitoring network has been installed during the construction of the dam. An automatic monitoring system, centralized in the warden house via cable, reads most of the measurements (259 sensors are automatically recorded, on a total of 971). Many instruments were installed for a detailed monitoring of the structure's behaviour during construction and the first filling phase. In the current normal operation, the on-line surveillance of dam performance is based on a subset of measurements.

In parallel to the on-line system, the off-line surveillance activities performs analysis of the measurements, automatically or manually recorded, verifying the dam's behaviour, by the comparison to the prediction of the three-dimensional F.E. model.

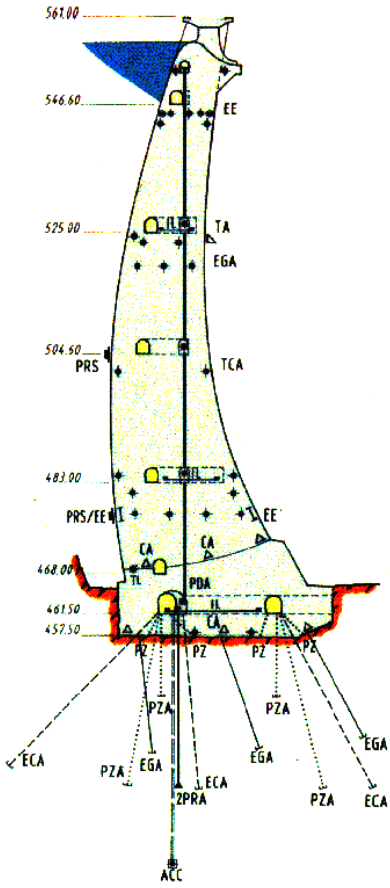

Figure 2: Ridracoli dam: monitoring system of the crown section

HYDROLOGICAL AND HYDRAULIC ASPECTS

Hydrological and hydraulic aspects are fundamental with respect to the safety of a dam. The reservoir capacity is 33.06 Mm^3, the catchment area is about 37 km^2. At the Ridracoli dam site a monitoring system has been installed for reservoir monitoring and management, in particular for the management of the water supply and to foresee flood events. On the basis of the measured data and of the water balance in the reservoir, the inflow and the outflow are computed and both displayed in the Internet page.

If high floods are expected and, in any case, if the outflow is excess of 50 m^3/sec (that corresponds to 10% of the spillway capacity) those responsible for the dam have to start up the extraordinary surveillance and alert the Civil Protection Dept. The surveillance condition and the dam safety conditions is reported on Internet.

STATIC STRUCTURAL BEHAVIOUR ANALYSIS

A decision support system (named MISTRAL) was installed in 1992 on a personal computer connected to the automatic monitoring system in the acquisition Centre, located in the warden house near the dam.

Mistral is a decision system for evaluating, explaining and filtering the information collected by the most important instruments connected to the automatic monitoring system, providing on-line interpretation of the behaviour of the structure in order to support the activity of the personnel responsible of the safety surveillance, requiring his intervention in case of anomalous situation, if any.

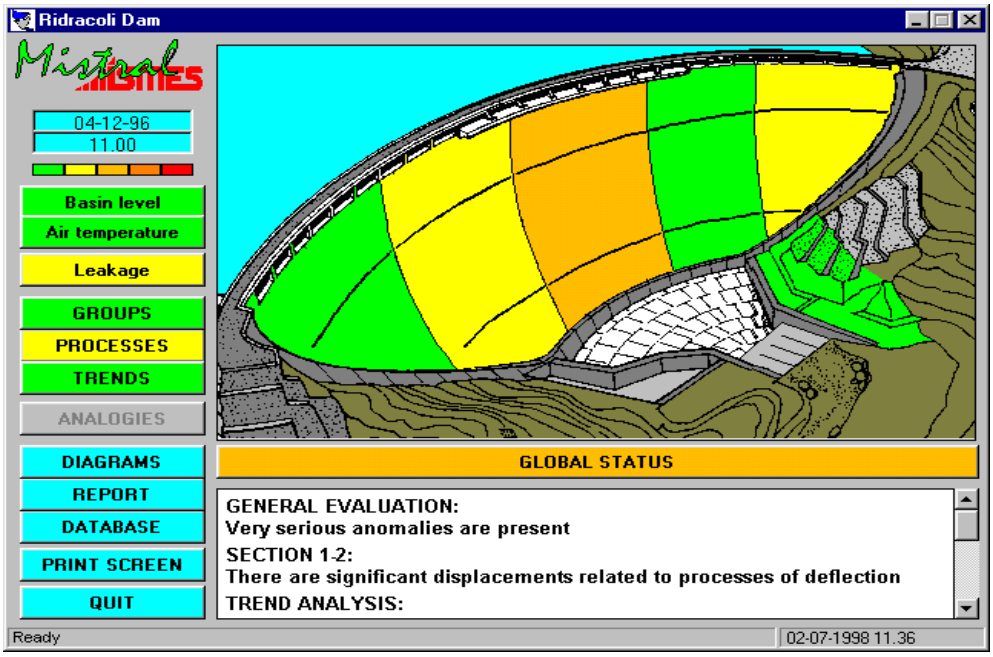

Figure 3: Mistral Interface: General state of the dam (test situation)

The on-line system makes it possible to verify the state of each measurement with respect to threshold levels (physical threshold, measured rate of variation and reference structural model), using knowledge about the significance and, reliability of each instrument, and evaluates the current state of the dam and of any elementary structural part, identifying any anomalous process and verifying the reliability of the measurements by consistency checks. The Mistral system currently operates taking into account the data collected hourly by 40 instruments.
Mistral displays the results of the analysis through a colour-based graphical interface that represents the state of the measurements, of the processes, of each section and of the entire structure under evaluation giving relevant explanations.
If the processed "global status" of the dam corresponds to alert conditions, (level 5 or red colour in the Mistral interface) the extraordinary surveillance enters in force and the Civil Protection Dept is alerted. The surveillance and the dam safety conditions are reported on the Internet page.

SEISMIC STRUCTURAL BEHAVIOUR ANALYSIS

The seismic monitoring system is made of four accelerometric stations and by one seismic station (each station has instruments installed in the three directions). The system allows to measure both the input ground motion and the structural answer of the dam.

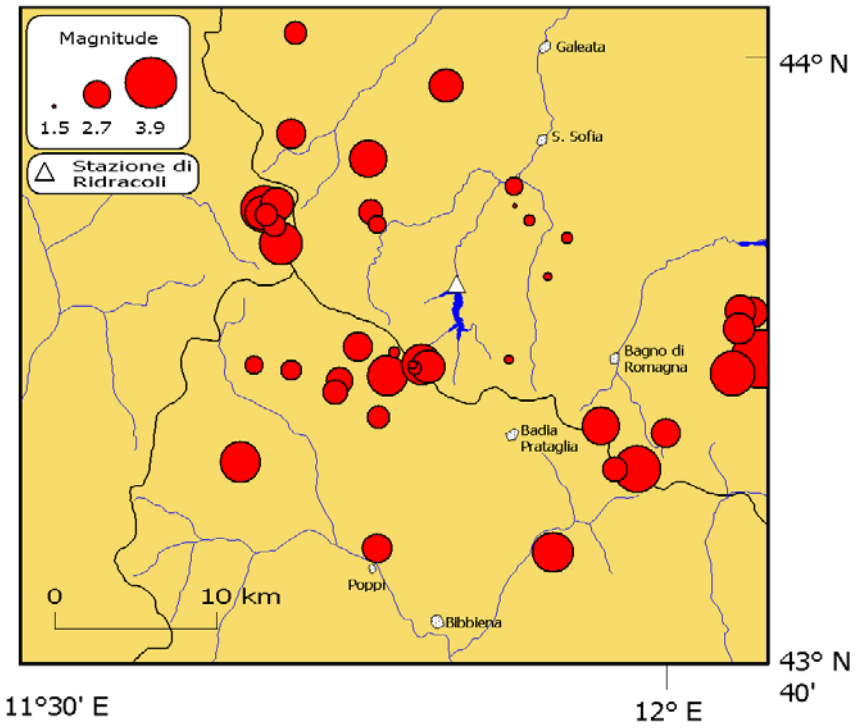

Figure 4: Local earthquakes collected by the seismic monitoring system

In the last period (1995-January 2003) the system collected 128 earthquakes that exceeded the trigger threshold. 63 were far from the dam site and 65 local (epicenter distance nearby 25 km from the dam site, as suggested by Dam's Authorities).

If the peak ground acceleration of the earthquake, measured at the base of the dam, is higher than 0.20 g (that corresponds to the seismic value obtained by the physical model that shows the beginning of cracks in the upper part of the dam, near the spillway sill), those responsible for the dam have to start up extraordinary surveillance (such as *ad hoc* inspection and collection of the whole measurements) and alert the Civil Protection Dept. The surveillance condition and the dam safety condition is reported on the Internet page.

The recorded seismic measurements, are periodically stored into the historical data base and processed to analyze the dam's behaviour, in comparison to the calculated one by a three-dimensional F.E. model and to the dynamic response retrieved from the vibrating test data.

INTERNET PRESENTATION

In the Internet home page of Romagna Acque much information is available relevant to the company, the water supply system and the dam.

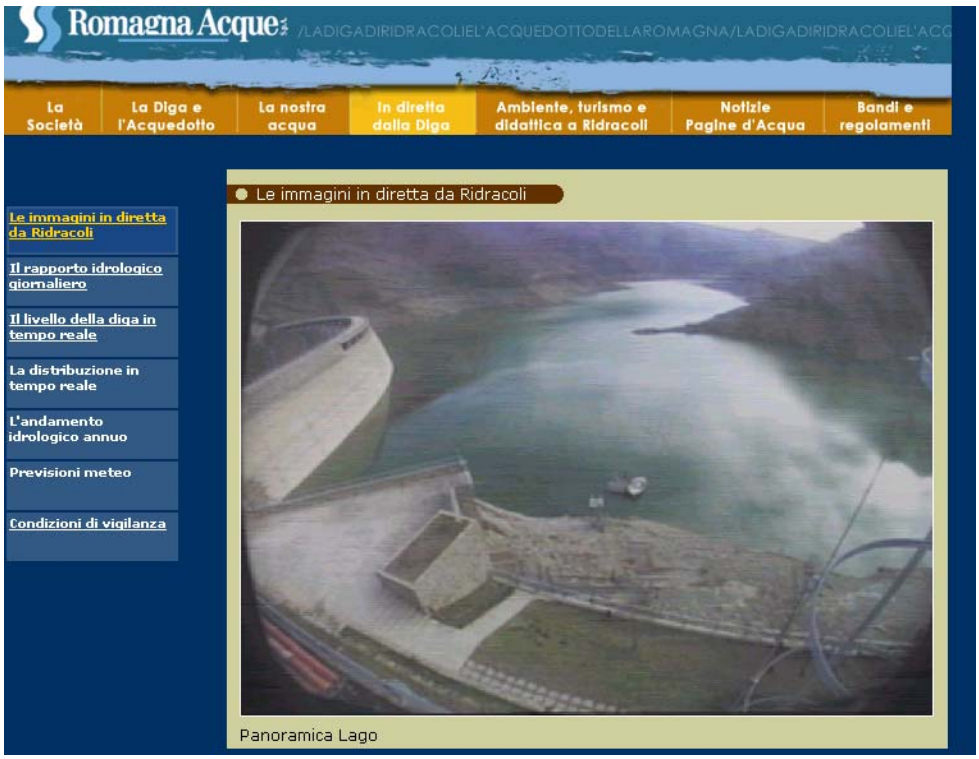

Figure 5: On-line images from the dam

In addition to the quality parameters of the water, the production and distribution of drinkable water, many data about the dam are reported, as illustrated in the following figures. The information reported is up-dated every hour.

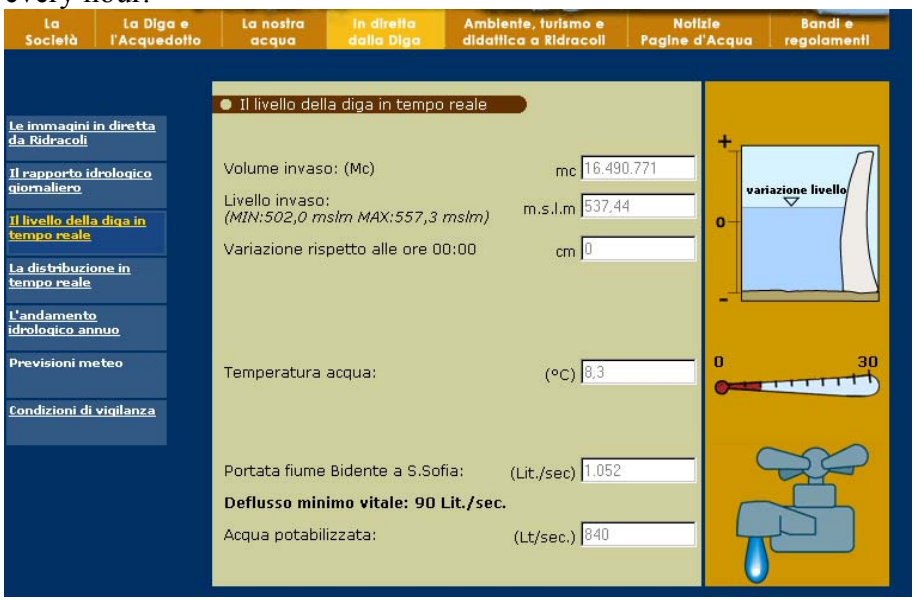

Figure 6: On-line water level in the reservoir

Figure 7: Water supply distribution

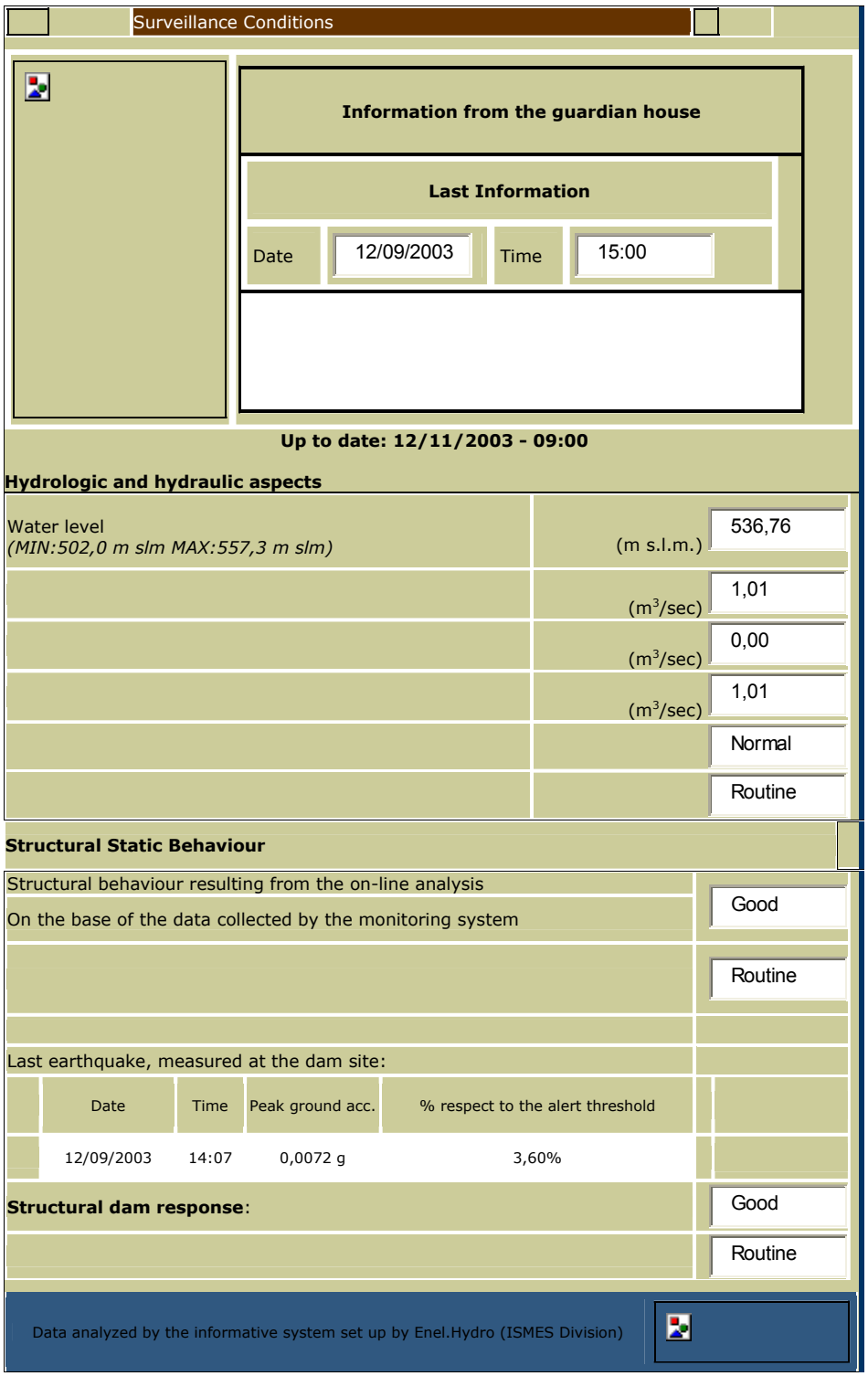

Figure 8: Safety and Surveillance Conditions (translated from Italian)

In the previous figure, the dam surveillance condition, together with the safety evaluation, is reported with respect to hydraulic, static and seismic safety assessment.
On average, the website is visited 40-50 times each day.
The local administration and residents downstream of the dam have given positive indications even though they report that some of the information provided is not always easy to interpret. In particular, reference is made to the difficulty of interpreting the definitions of *Surveillance Conditions.* In view of this feedback, the website Introductory Page is now in the process of revision by the incorporation of additional explanatory notes.

CONCLUSION

Monitoring and data analysis are primary parts in managing the safety of dams by risk assessment methodology. At the Ridracoli dam the on-line data analysis and the surveillance management have became a part of the safety procedures of the dam. The results of such activities are available to the population living in the downstream valley, by Internet network and by video installed in each City Hall.

This is the first time in Italy that the results of risk assessment methodology has been used on-line and available on the Internet.

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