

**EDF French studies on mechanical strength of spillway gates and bottom outlet valves under earthquake loading**

# SUMMARY

## 1.Introduction

Few gates damaged by earthquake  
Increasing risk management

## 2.EDF first analysis

Analysis of existing documentation  
Analysis on spillway gates  
Analysis on bottom outlet  
Discussions with Japanese Engineers

## 3.Conclusion and proposal

Technical proposal

# Introduction (1)

**Increasing demand to take into account seismic risk;**

**Recent events that have hit Italy make us wonder;**

**New projects in foreign countries with frequent earthquakes;**

**Gates and ancillary equipments are also concerned.**

## Introduction (2)

**Examples of gate ruin of gates due to earthquake seem to be scarce and difficult to find :**

- Sefidrud Dam in Iran in 1990
- Wenchuan earthquake in China in 2008
- Shih-Kang dam in Taiwan in 1999 is the most spectacular, but the gates are still present





# Introduction (3)

## One example of damage on gates due to earthquake in France : Vinça Dam :

➤ Concrete Dam in service since 1976

➤ 55 m high – 192 m long in crest

➤ Flood prevention purpose

➤ Not operated by EDF

➤ Spillway equipped with 2 radial gates: 16,30 m large 8m high, in crest



# Introduction (4)

- Earthquake on 1996 February 18th – magnitude 5.3 on Richter scale (moderate; intensity VI to VII)
- Reservoir was half empty
- Gates were opened, but one 4 m, the other 2 m
- Only one gate was damaged (opened 4 m):
  - Skin plate (15 mm thick) was deformed
  - One stiffener deformed
  - Sealing crushed
- Description gives the impression that gate has experienced a lateral shock, parallel to the skin plate.

Vinça is the only experience of damage on a french dam (and gate)

# Introduction (5)

**The available feedback seems to show that hydroelectric equipments and particularly gates and valves are generally not damaged by earthquakes,**

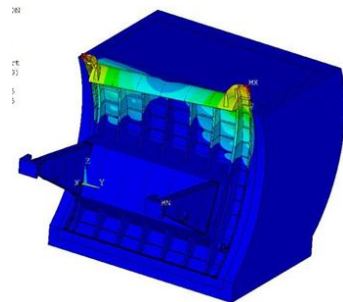
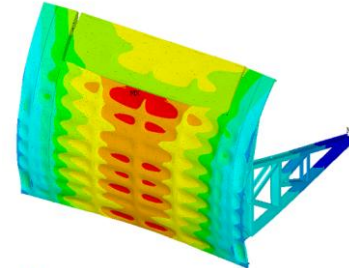
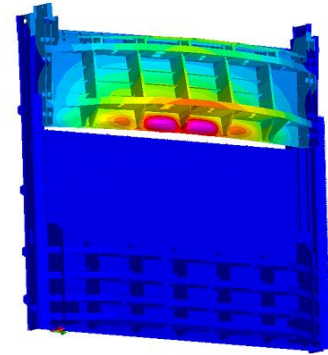
**But it is extremely difficult to demonstrate this**

**The state of current knowledge does not allow to define simple rules of dimensioning which are representative of the feedback of experience**

# EDF First Analysis on spillway gates (1)

First investigations about gates have pointed several topics:

- Hydrodynamic pressure (applying Westergaard formula to spillway gates) is it really representative ?
- Added masses of water for numerical calculations is not representative of dynamic behavior of gates;
- Dynamic behavior of gates can be very different from one gate to another;
- Floor amplification for crest gates;
- Bottom outlet gates : any amplification due to galery ?





# EDF First Analysis on spillway gates (2)

- Comparison between finite element modeling using Fluid-structure interaction (FSI) and experimental investigations on radial gate shows that :

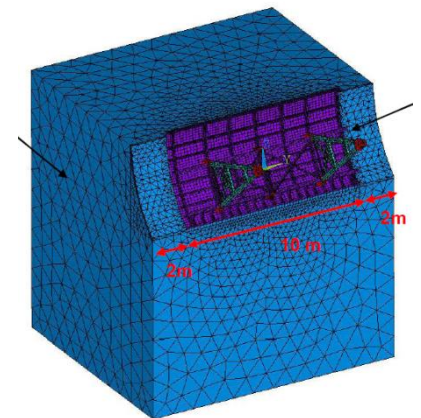
- model gives Eigen frequencies that comply fairly with measurements.



**BUT...**

- Spectral modal analyzes give (very) overestimated results, compared to observations

This leads to the conclusion that dissipative or non linear phenomena exist and should be quantified



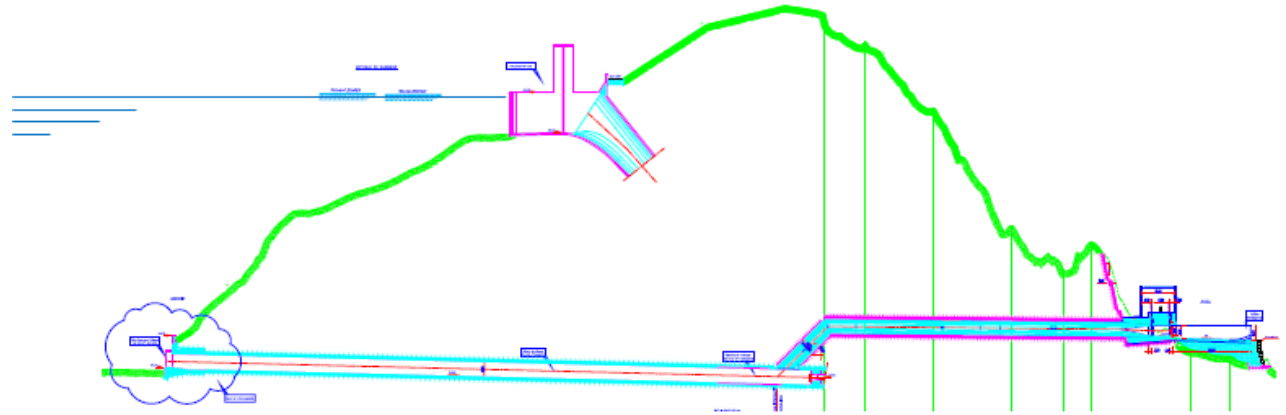
# EDF First Analysis on spillway gates (3)

- In the field of dams calculation, engineers deal with soil-fluid-structures interaction.
- For gates and valves we must consider the support-structures or anchor-structures interactions :
  - mechanical clearance,
  - seals influence,
  - sliding of anchors,
  - local behavior of civil works at the level of the supports of the gates and valves

This will likely lead to complex analyzes for which field-measures seem essential if we seek realistic approaches.

# EDF First analysis on bottom outlet (1)

## Bottom outlet



**Results of numerical simulations, without dissipation of energy, are very (too?) overestimating**

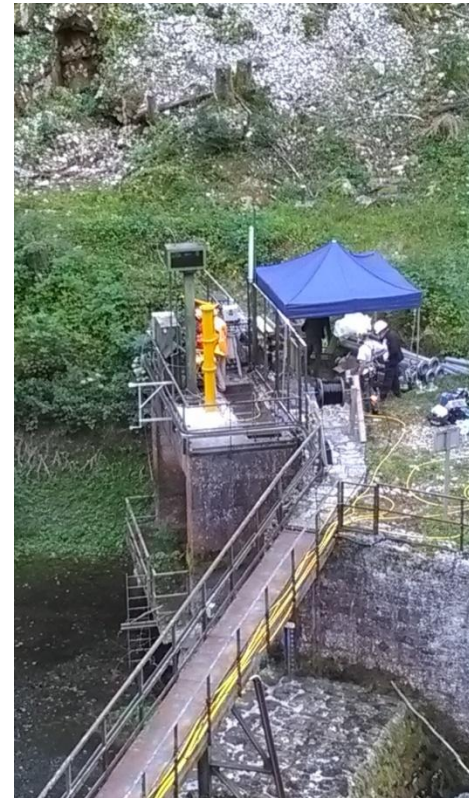
**Identify and characterize any sources of energy dissipation, at the inlet, along the duct, to the valve**

## EDF First analysis on bottom outlet (2)

- August 2016 : test campaign on a French development
- Feasibility seems to be achieved
- Measurement of an attenuation, but we are not yet able to characterize a damping effect

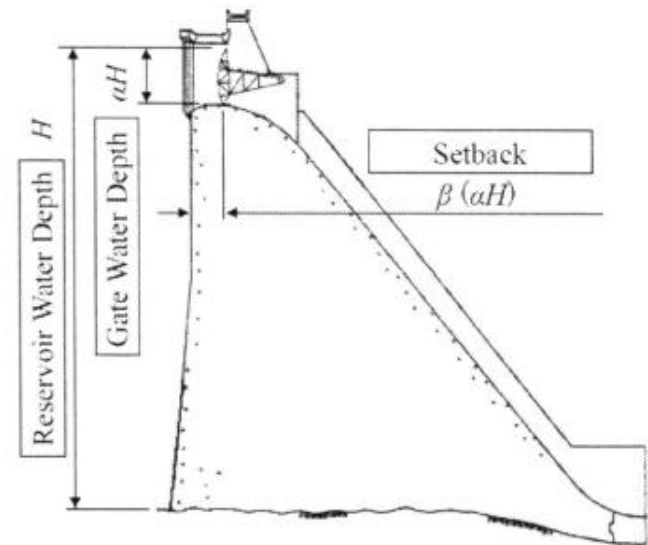
The attenuation seems to depend on the Eigen modes of the gallery (form gallery, materials), frequency of pressure waves, behavior of the valve

➔ Ideal would be to have measures ON THE VALVES



# Technical discussion with Japanese engineers (1)

- Westergaard's formula is not reliable for high dam crest gates (overestimation)
- Geometrical position of gate on seal can reduce overpressure ("set back")
- Many simulations on shaking tables.
- Cases of bottom outlet are specific

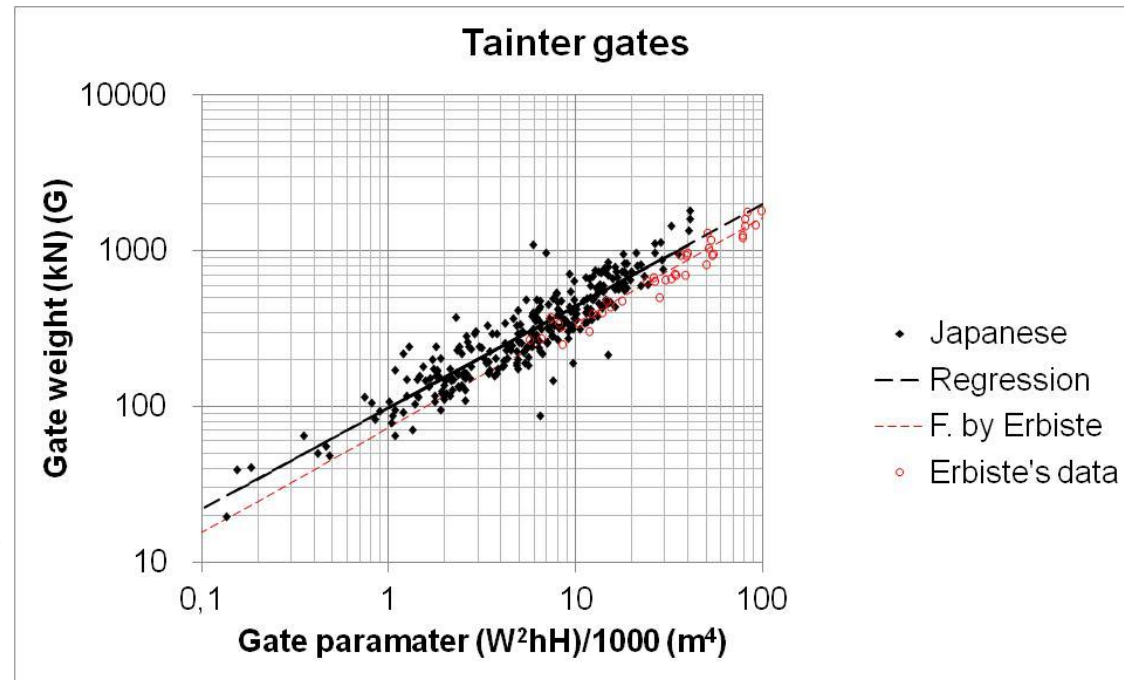


➔ It is difficult to edit simple dimensioning rules

# Technical discussion with Japanese engineers (2)

## Survey EDF with Japanese engineers :

- Japanese gates are heavier than French gates;
- This overweight is due to earthquake dimensioning ;
- The mean overweight for spillway radial gates is 10% .





# Conclusion and proposal (1)

After analysis of EDF first studies and discussions with Japanese Engineers,

- EDF CIH concludes that it is actually difficult to justify the good mechanical behavior of the gates and valves that seems to be observed.
- The engineers have to explore the "hidden margins" in equipment and conservatisms in methods. This involves the analysis of measurements or recordings carried out directly on the valves
- EDF realizes that EDF has not enough experimental investigations on gates and valves.

## Conclusion and proposal (2)

**Proposal:** each European project manager operating hydroelectric facilities could instrument some equipment and share this data (Equipped with accelerometers and wireless data acquisition systems).

Italy being a country subject to regular and high energy seismic stresses, the data provided could be of great scientific interest.

The EDF engineering within the framework of EWG “Dams & Earthquakes” may make his contribution to any owner ready to record and interpret data measured on gates and valves.

## Conclusion and proposal (3)

We have worked extensively on the analysis of the integrity of the gates and valves, which is a prerequisite

It is now necessary to start working on the post-earthquake operability of gates and valves

Again, a sharing of experience is required to record data and analyze them to evaluate gate and valve performances during and after earthquakes