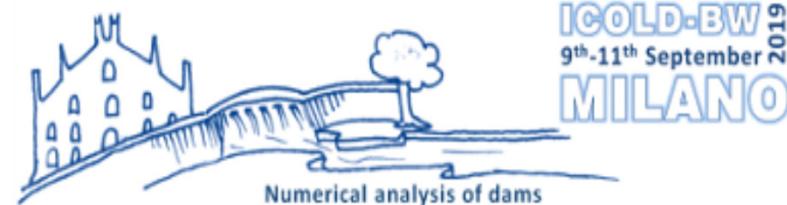




**ICOLD**  
INTERNATIONAL  
COMMISSION ON  
LARGE DAMS



## **ICOLD COMMITTEE ON COMPUTATIONAL ASPECTS OF ANALYSIS AND DESIGN OF DAMS**

### **15<sup>th</sup> INTERNATIONAL BENCHMARK WORKSHOP ON NUMERICAL ANALYSIS OF DAMS**

**Theme A**

**9 September 2019, Milan, Italy**

*Dynamic Analysis of Pine Flat Concrete Dam  
Acoustic fluid-structural interaction with ANSYS Workbench*

**CADFEM<sup>®</sup>**

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a Gruner company



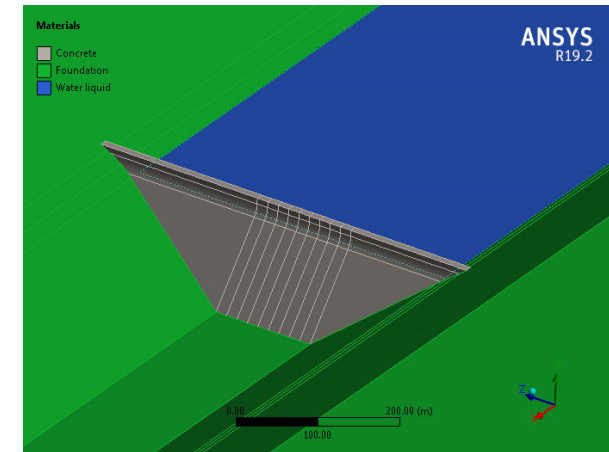
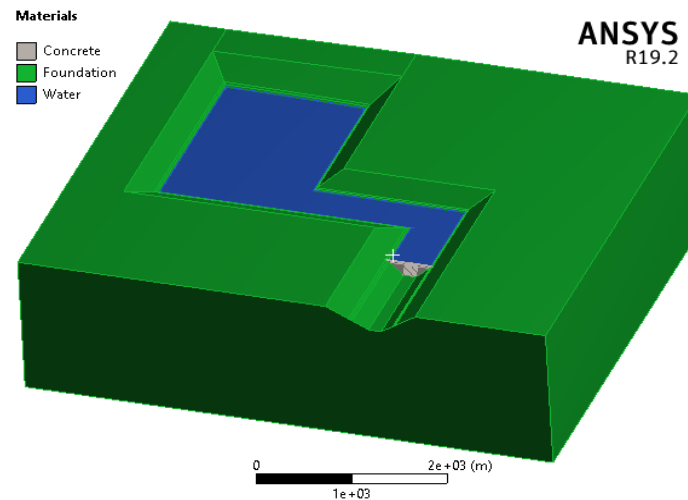
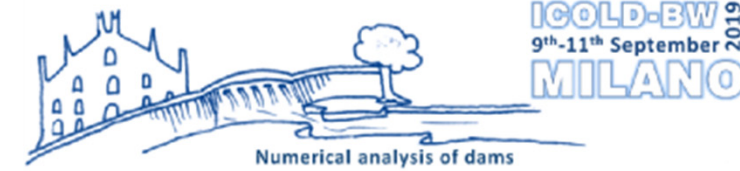
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*T. Menouillard, A.D. Tzenkov, M.V. Schwager*

## Particular aspects of the paper presented

- 3D-model of the dam, its foundation and the reservoir
- Fluid structure interaction is addressed introducing an acoustic domain for the reservoir.



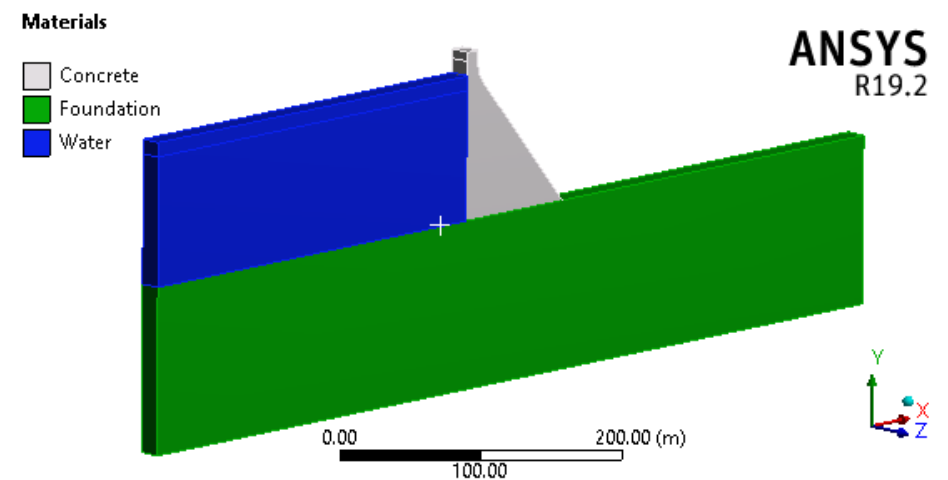
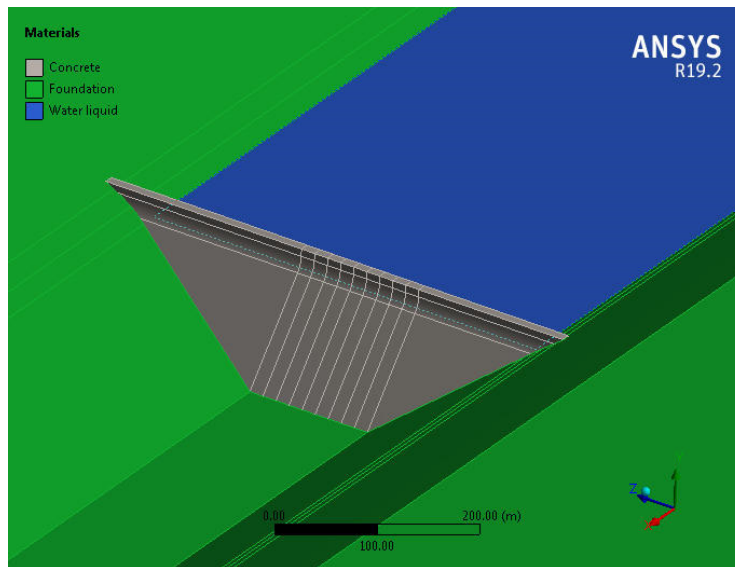
# Results of the eigenvalue analysis



3D-model

vs

2D-model (block no. 16)



# Results of the eigenvalue analysis

## 1<sup>st</sup> mode, water level at 268.21m asl



### 3D-model

$f_1 = 2.79$  Hz

vs

### 2D-model (block no. 16)

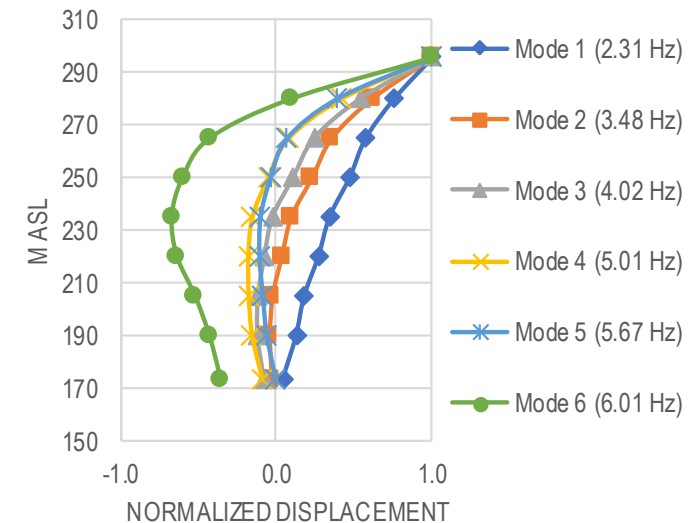
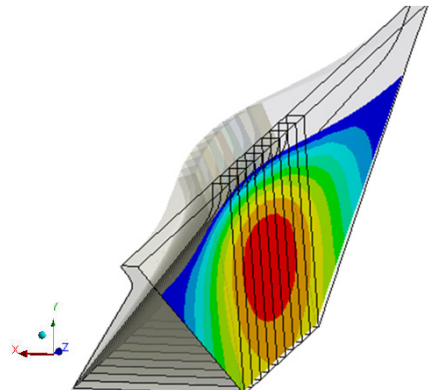
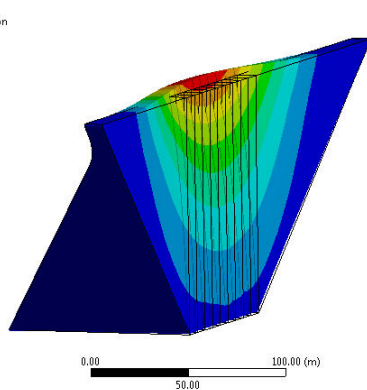
$f_1 = 2.31$  Hz

Total deformation

Hydrodynamic water pressures

D: Modal  
Total Deformation 8  
Type: Total Deformation  
Frequency: 2.7963 Hz  
Sweeping Phase: 0. °  
Unit: m

2.7842e-7 Max  
2.4748e-7  
2.1655e-7  
1.8561e-7  
1.5468e-7  
1.2374e-7  
9.2806e-8  
6.187e-8  
3.0935e-8  
0 Min



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# Results of the eigenvalue analysis

## 1<sup>st</sup> mode, water level at 278.57m asl



### 3D-model

$f_1 = 2.67 \text{ Hz}$

vs

### 2D-model (block no. 16)

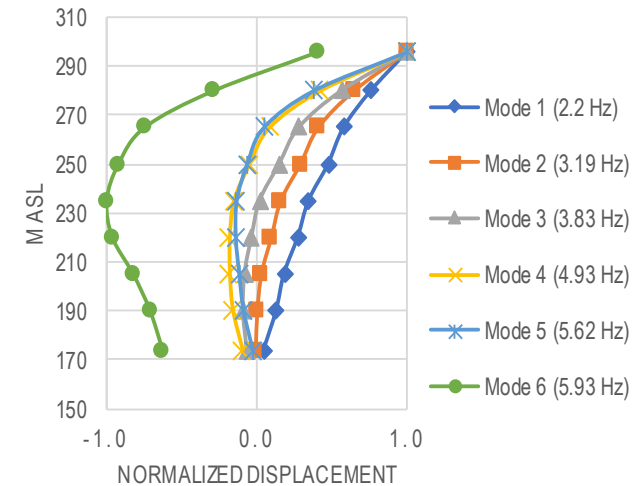
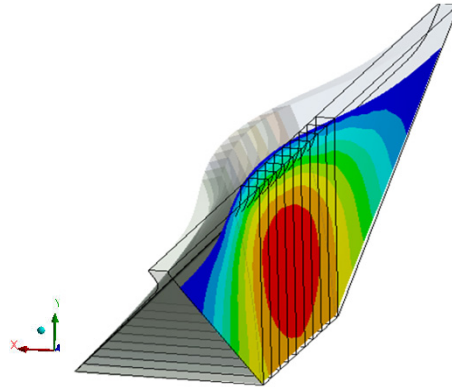
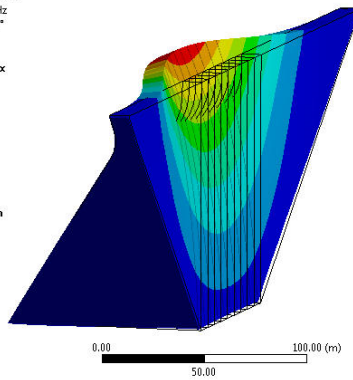
$f_1 = 2.20 \text{ Hz}$

Total deformation

Hydrodynamic water pressures

**Mt: Modal Acoustics**  
Total Deformation - Mode 8 - 2.6736 Hz - Multiple  
Type: Total Deformation  
Frequency: 2.6736 Hz  
Sweeping Phase: 0. °  
Unit: m

2.1224e-7 Max  
1.8893e-7  
1.6563e-7  
1.4233e-7  
1.1902e-7  
9.572e-8  
7.2417e-8  
4.9113e-8  
2.5809e-8  
2.5058e-9 Min



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T. Menouillard, A.D. Tzenkov, M.V. Schwager

# Results of the eigenvalue analysis

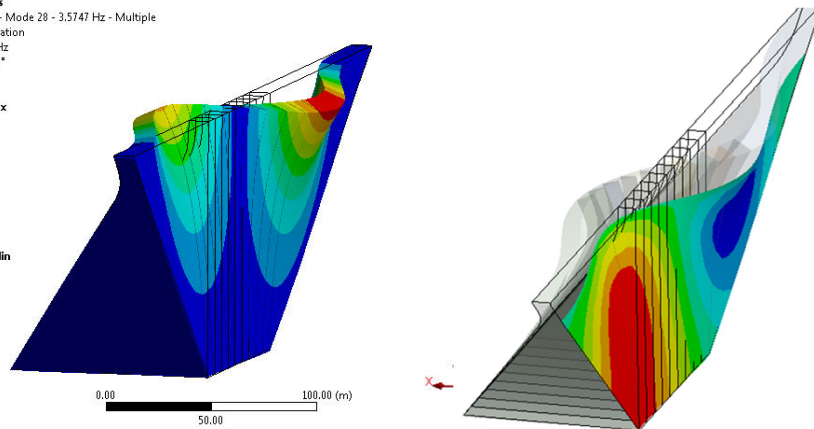
## 2<sup>nd</sup> and 3<sup>rd</sup> mode (3D-modes), water level at 278.57m asl



2<sup>nd</sup> mode,  $f_2=3.57$  Hz

**M: Modal Acoustics**  
Total Deformation - Mode 28 - 3.5747 Hz - Multiple  
Type: Total Deformation  
Frequency: 3.5747 Hz  
Sweeping Phase: 0. °  
Unit: m

1.2852e-7 Max  
1.1432e-7  
1.0013e-7  
8.593e-8  
7.1734e-8  
5.7537e-8  
4.3341e-8  
2.9144e-8  
1.4948e-8  
7.5108e-10 Min



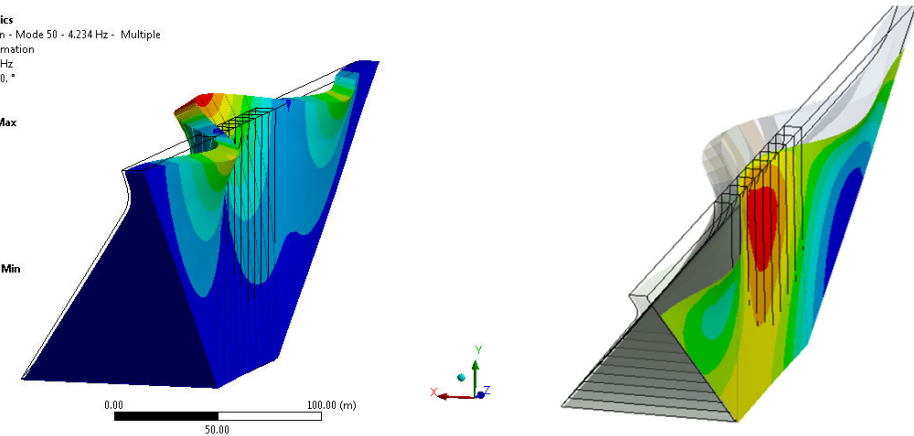
Total deformation

Hydrodynamic water pressures

3<sup>rd</sup> mode,  $f_3=4.23$  Hz

**M: Modal Acoustics**  
Total Deformation - Mode 50 - 4.234 Hz - Multiple  
Type: Total Deformation  
Frequency: 4.234 Hz  
Sweeping Phase: 0. °  
Unit: m

1.1657e-9 Max  
1.0388e-9  
9.1179e-10  
7.8484e-10  
6.5788e-10  
5.3092e-10  
4.0396e-10  
2.77e-10  
1.5004e-10  
2.3086e-11 Min

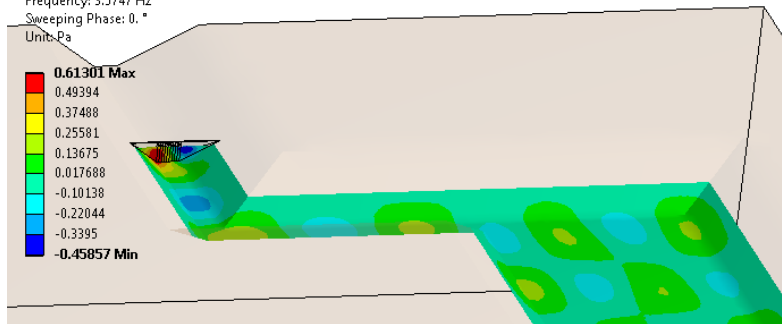


Total deformation

Hydrodynamic water pressures

**M: Modal Acoustics**  
Acoustic Pressure - Mode 28 - 3.5747 Hz - Multiple  
Type: Acoustic Pressure  
Frequency: 3.5747 Hz  
Sweeping Phase: 0. °  
Unit: Pa

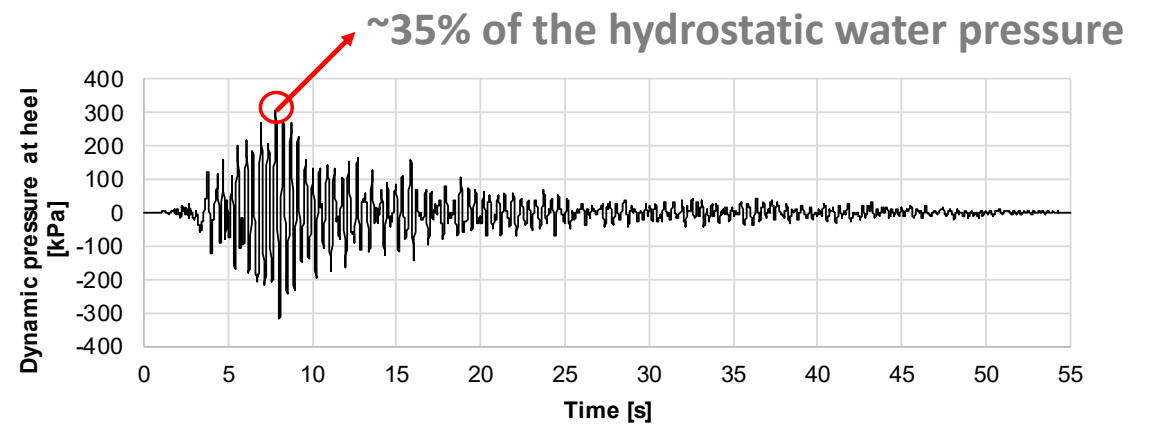
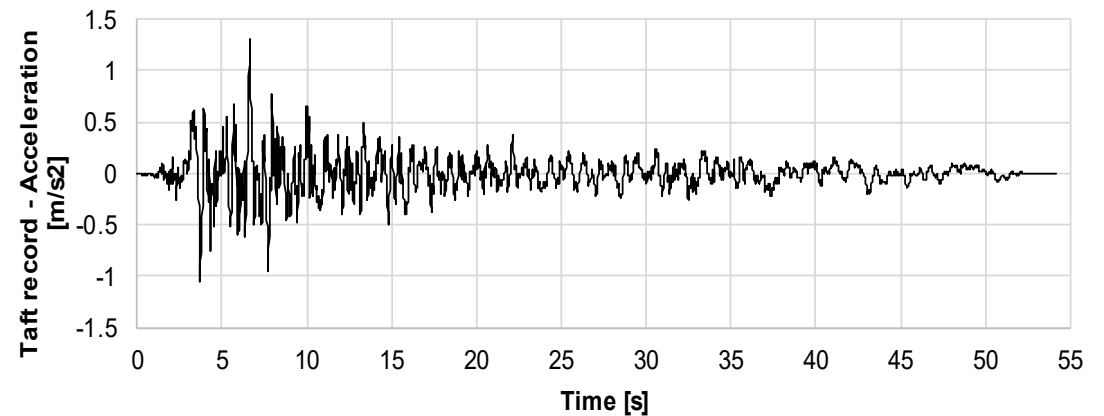
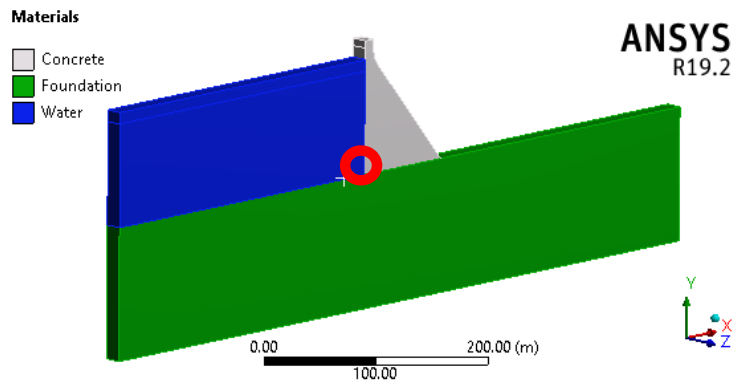
0.61301 Max  
0.49394  
0.37488  
0.25581  
0.13675  
0.017688  
-0.10138  
-0.22044  
-0.3395  
-0.45857 Min





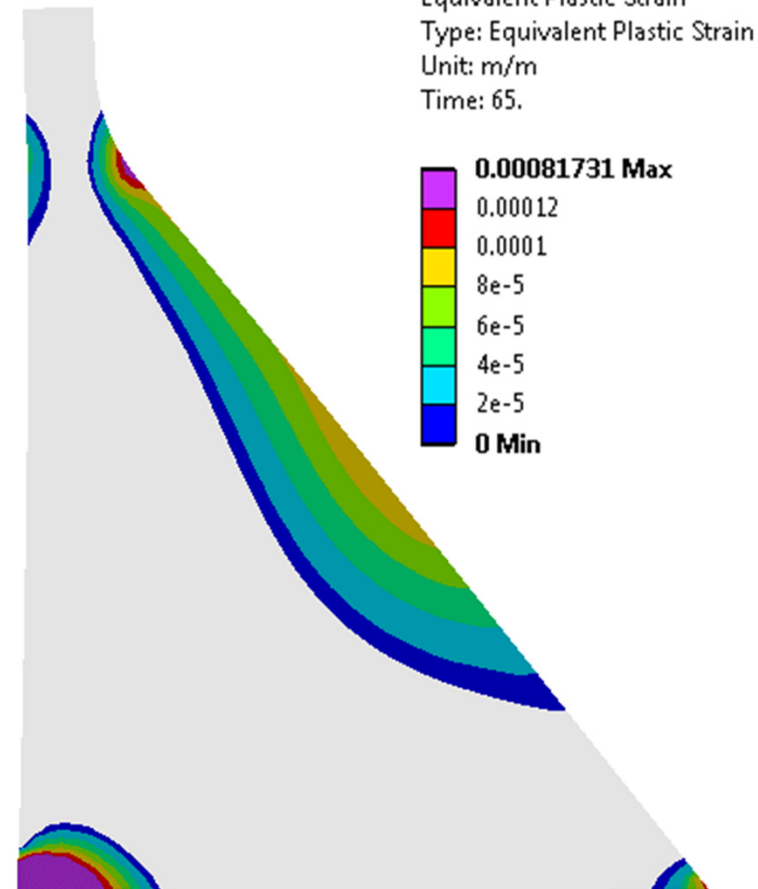
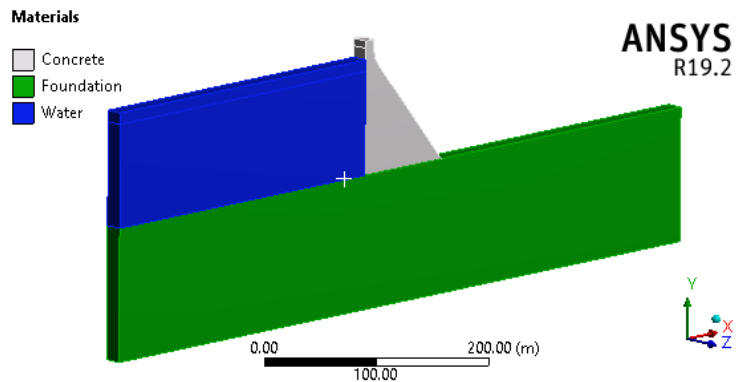
# Results of the seismic analysis (2D)

## Hydro-dynamic water pressures



# Results of the seismic analysis (2D)

## Plastic strains (Drucker Prager perfect plasticity)





# Conclusions



- Using today's computational tools, the 3D-geometry of the dam, the valley and the reservoir can be taken into account.
- As to be expected, the fundamental frequency is found to be higher for the 3D-model than for the 2D-model.
- The eigenfrequencies of the three dimensional modes are in the same range than the higher eigenfrequencies of the 2D-model.
- Introducing an acoustic domain is found to be appropriate to account for hydrodynamic water pressures.