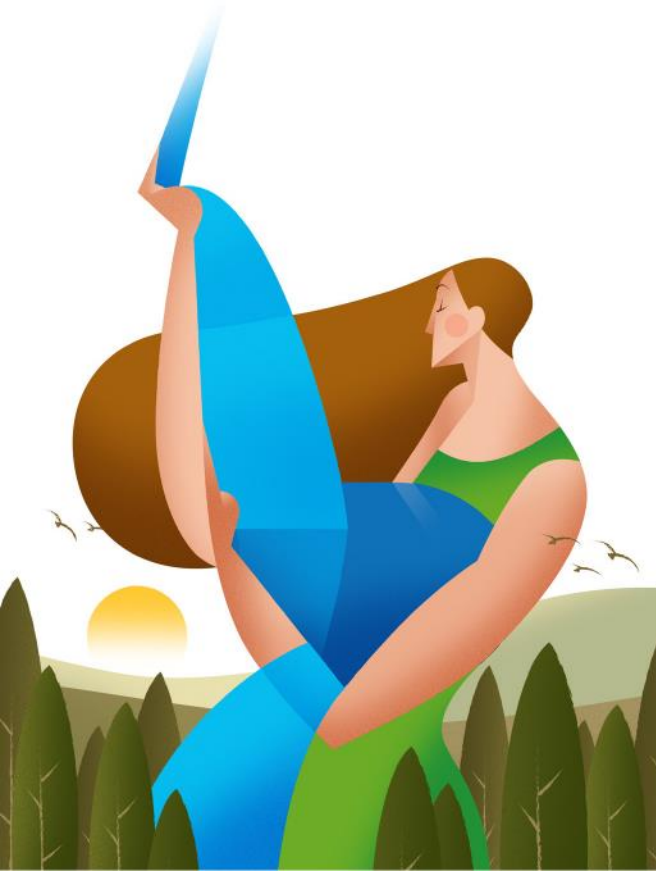
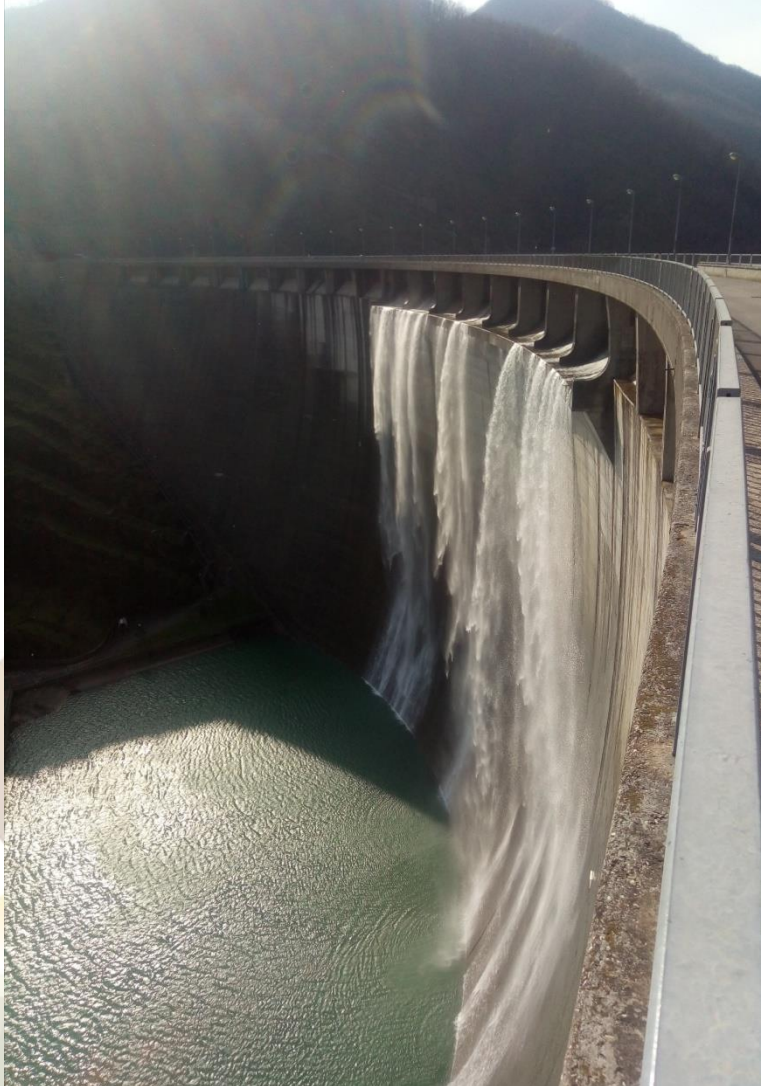


ELASTO-PLASTIC DAMAGE TIME- HISTORY ANALYSIS OF DAMS: THE CASE OF RIDRACOLI

PhD. Ing. Giulia Buffi





- **High accuracy and important details**

- **Local element behavior**

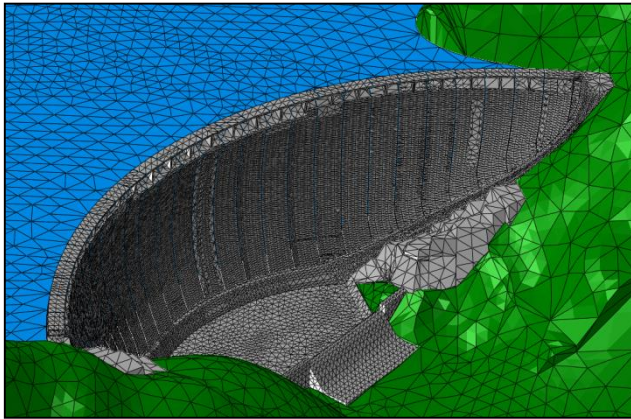


- **Tensile damage evolution under MCE event for different water levels**

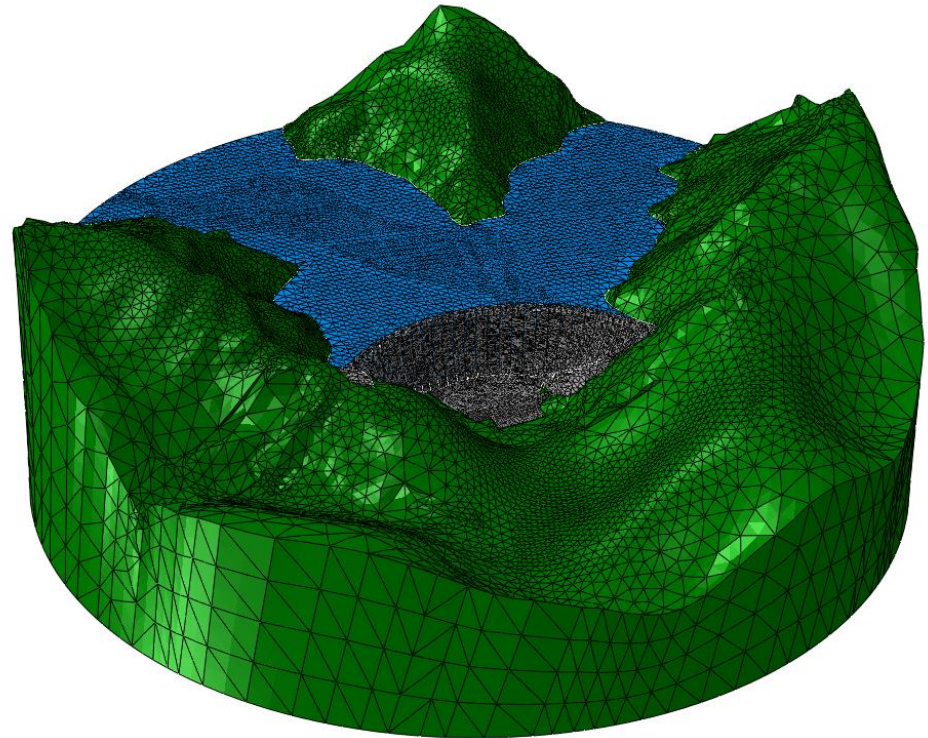
Outline: the arch-gravity Ridracoli dam



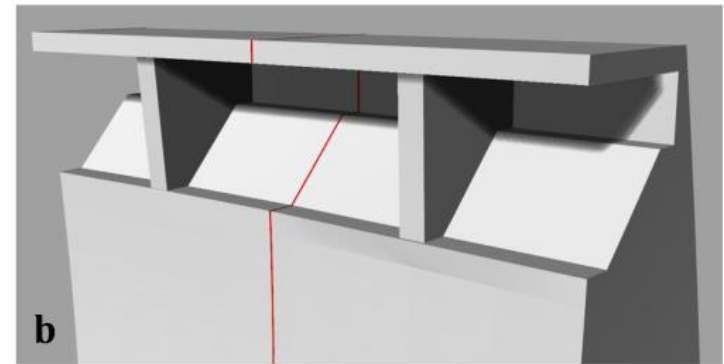
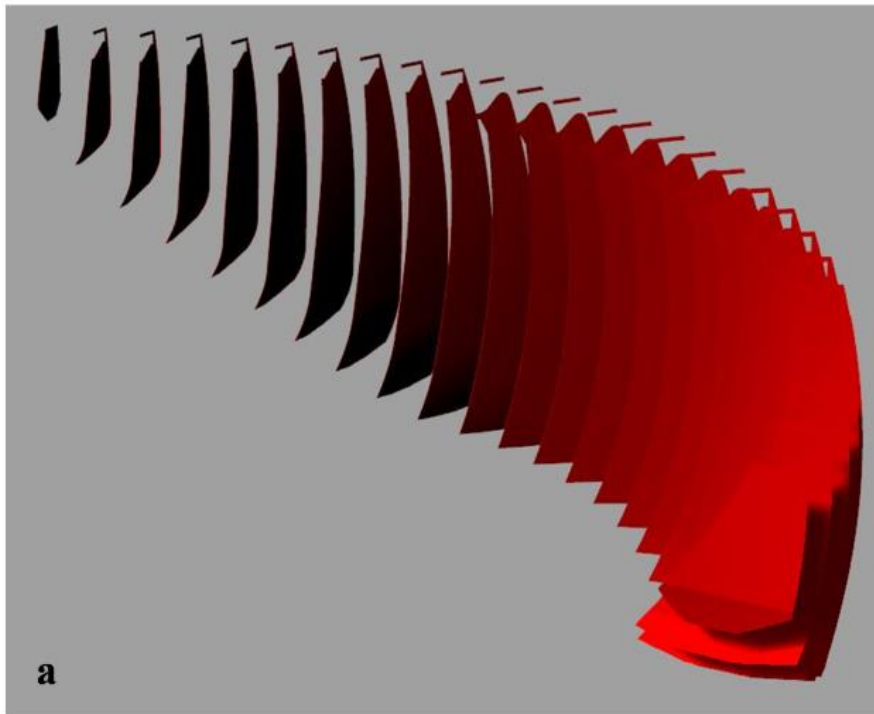
Maximum height:	103.500 m
Crest length:	432.000 m
Reservoir capacity:	33.000 million m ³
Maximum thickness (foundation):	36.000 m
Minimum thickness (dam crowing):	10.000 m



- **C3D4** for **rock mass** and **structure** and **AC3D4** (acoustic elements) for the **water**
- **Linear elastic** constitutive **behavior** for the rock mass and the blocks
- In dynamic analyses, $E_d > E_s$

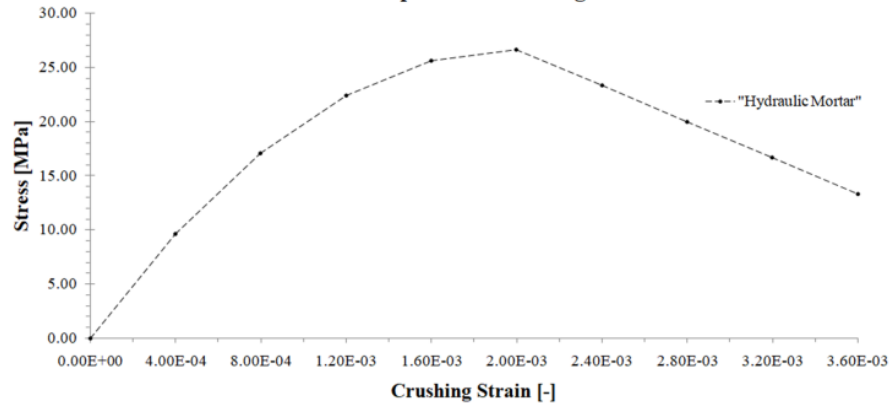


“Calibration of finite element models of concrete arch-gravity dams using dynamical measures: the case of Ridracoli”, Buffi G., Manciola P., De Lorenzis L., Cavalagli N., Comodini F., Gambi A., Gusella V., Mezzi M., Niemeier W., Tamagninia C., *Proceeding of EURODYN2017*, Rome (Italy).

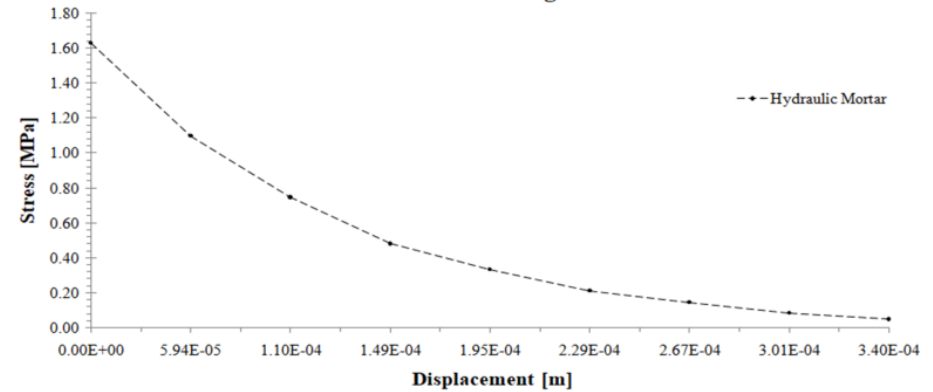


- **Vertical contraction joints as solid elements**

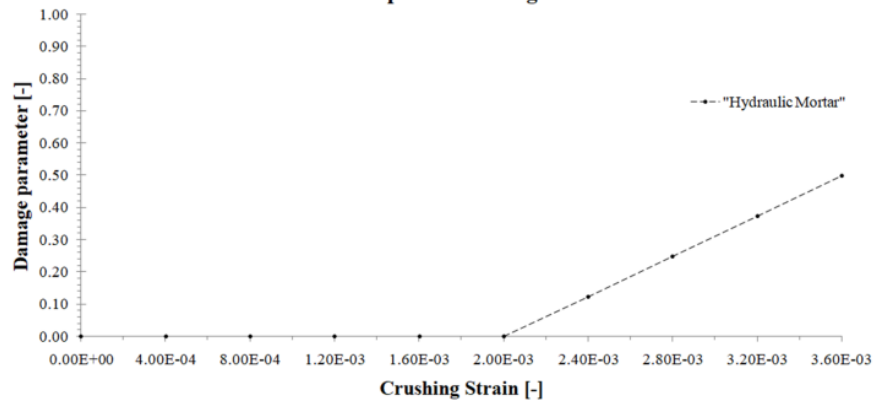
Compression hardening



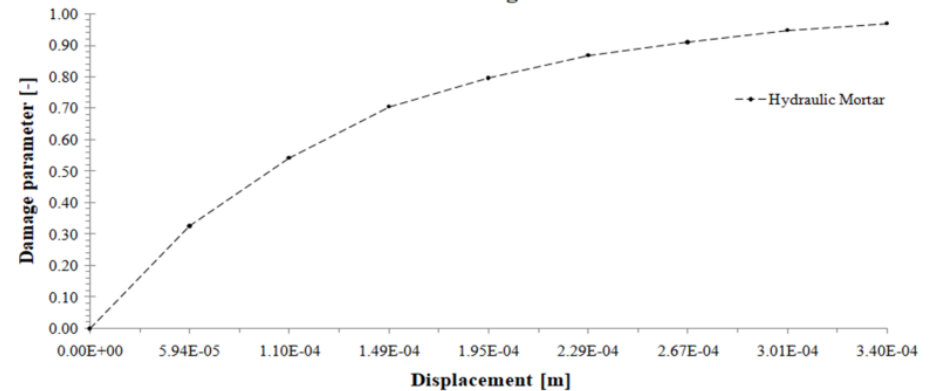
Tension Stiffening



Compression damage

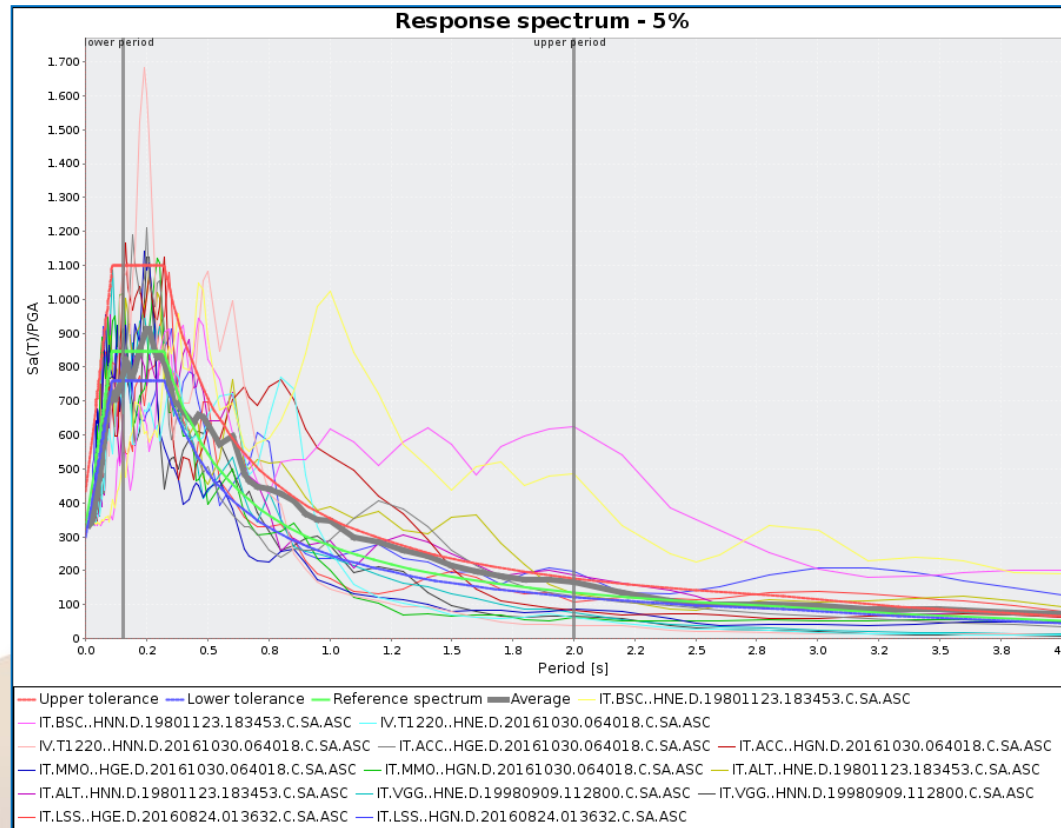


Tension damage



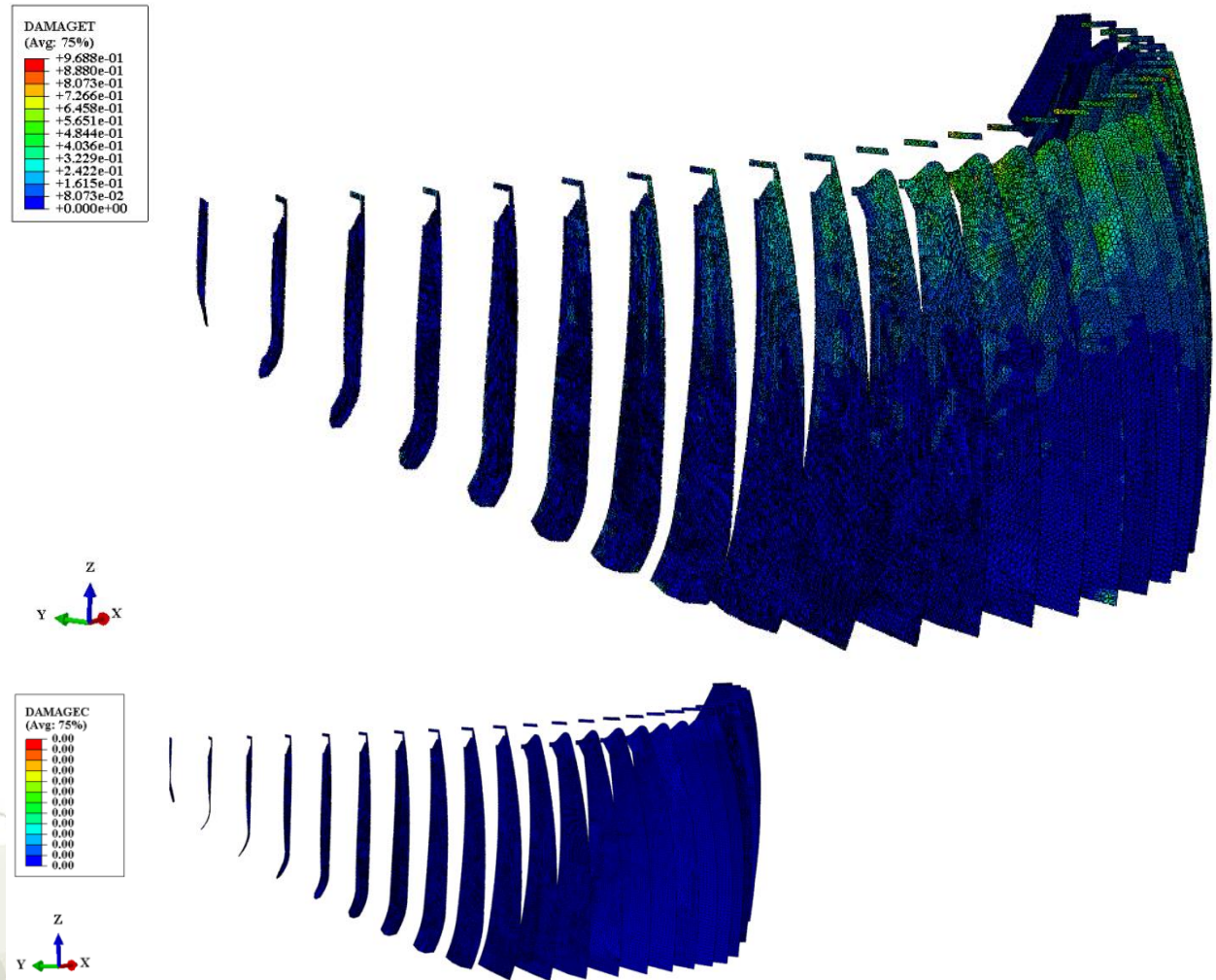
$$d_c = 1 - \frac{\sigma_c}{\sigma_{cu}}$$

$$d_t = 1 - \frac{\sigma_t}{\sigma_{t0}}$$

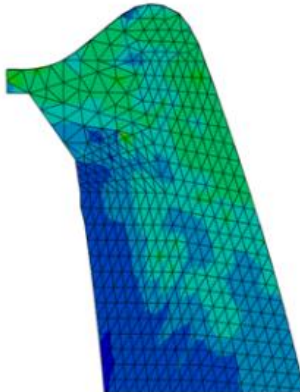
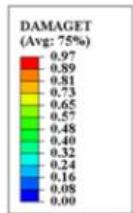


Station Place	Event time	Max PGA [m/s ²]	Duration [s]	M _L
Leonessa (RI)	24/08/2016 01:36:32	0.23	80.0	6
Accumoli (RI)	30/10/2016 06:40:18	5.47	60.0	6.1
Montemonaco (AP)	30/10/2016 06:40:18	1.85	60.0	6.1
Baregnano (MC)	30/10/2016 06:40:18	2.52	193.4	6.1
Auletta (SA)	23/11/1980 18:34:53	0.56	66.49	6.5
Bisaccia (AV)	23/11/1980 18:34:53	0.95	76.21	6.5
Viggianello (PZ)	09/09/1998 11:28:00	0.72	21.62	5.5

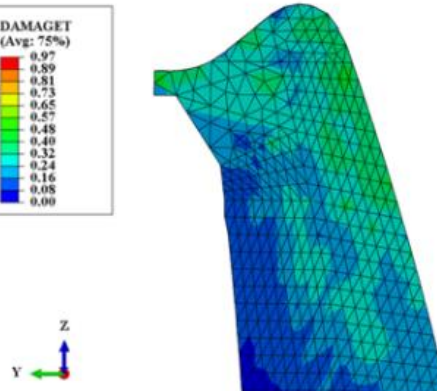
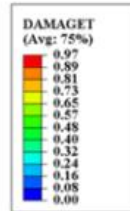
- **Non-linear elastic** constitutive behavior for vertical joint concrete
- **SLC** – Collapse Limit State – seismic input (Accumoli, Central Italy, 30/10/2016, $M_L=6.1$)
- **Three component acceleration** time-history (N-S, E-W, U-D)
- **Empty reservoir** condition



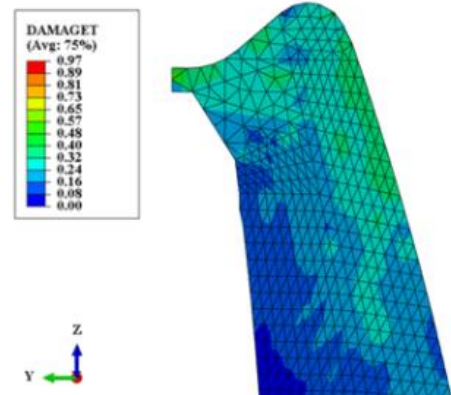
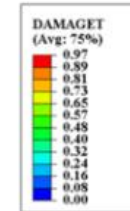
Elasto-plastic damage time-history analysis: damage T evolution varying the water level



Empty reservoir condition



Minimum operating level
(523m a.s.l.)

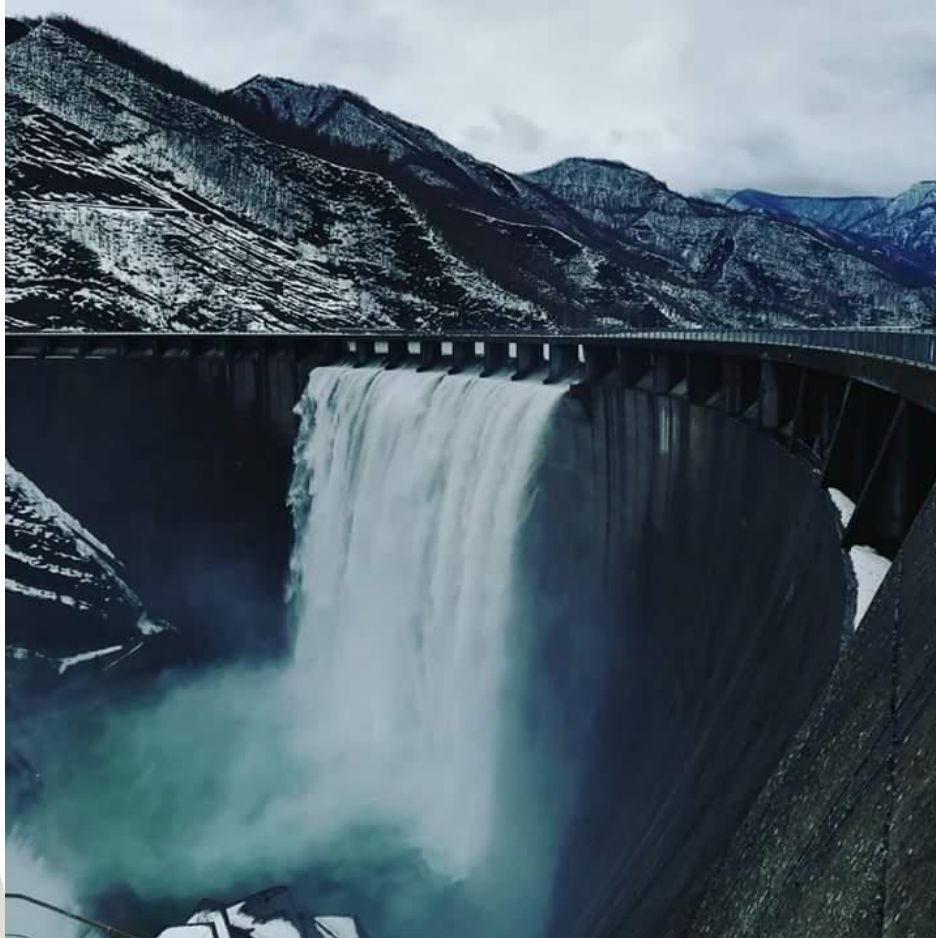


Normal reservoir level
(557.3m a.s.l.)

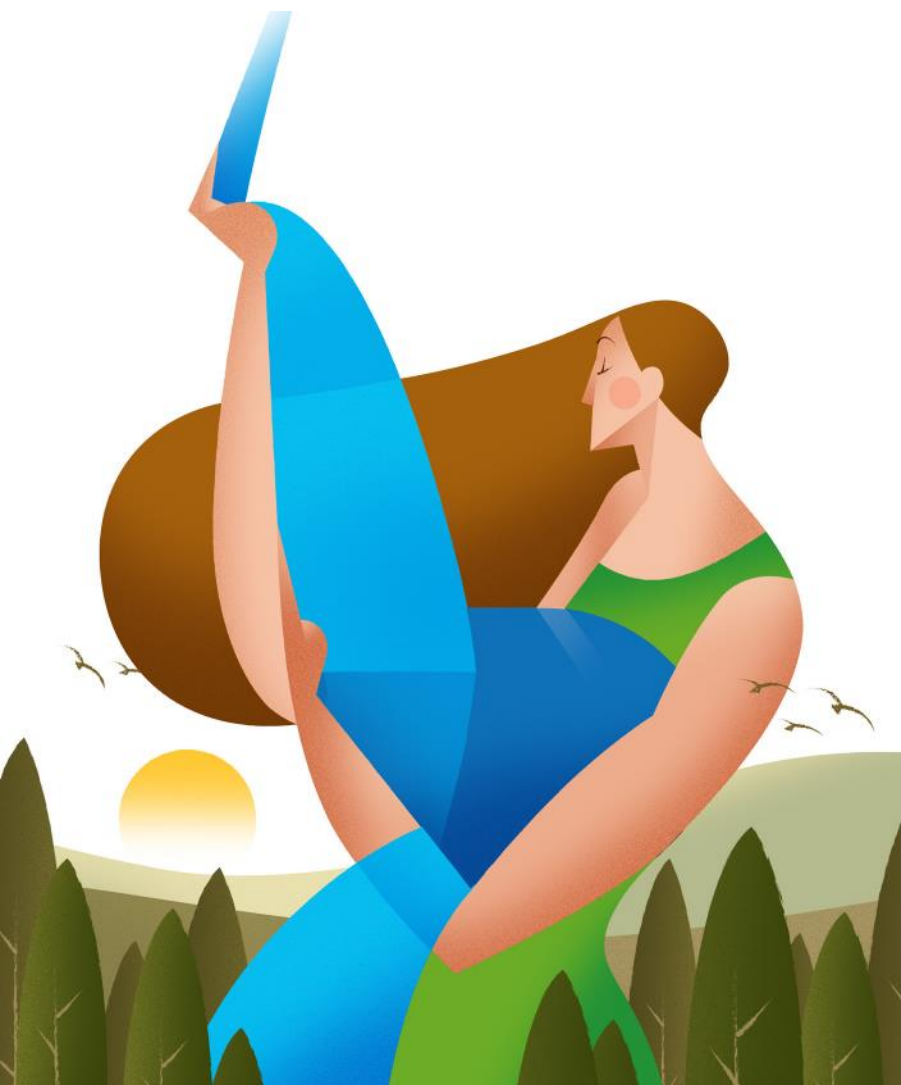
Water level



Damage T parameter propagation



- **High resolution survey techniques** are necessary to reproduce **small discontinuities**
- **Calibration of Rayleigh damping parameters** is necessary
- **Simplified models** can describe the **global dynamic behaviour**
- **Sophisticated models** investigate the **local behavior** and they verify the **seismic vulnerability assessment** of the **whole structure**



**THANK YOU FOR THE
ATTENTION**

gbuffi@romagnacque.it

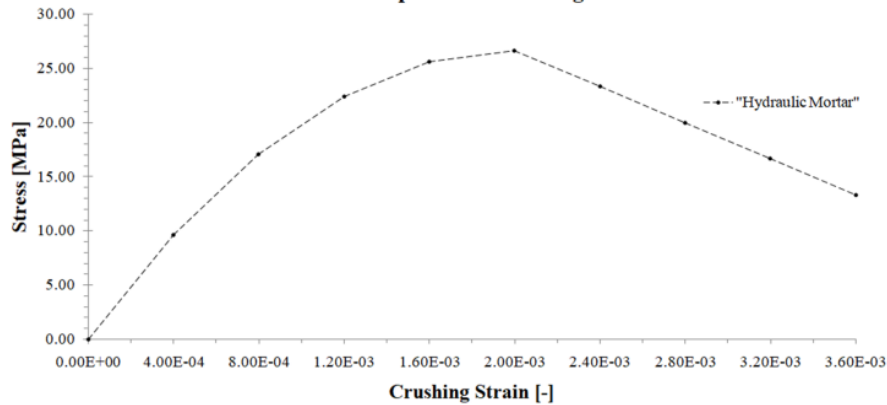
 **Romagna Acque**
Società delle Fonti S.p.A.

CDP – Concrete Damaged Plasticity – model of the vertical joint elements

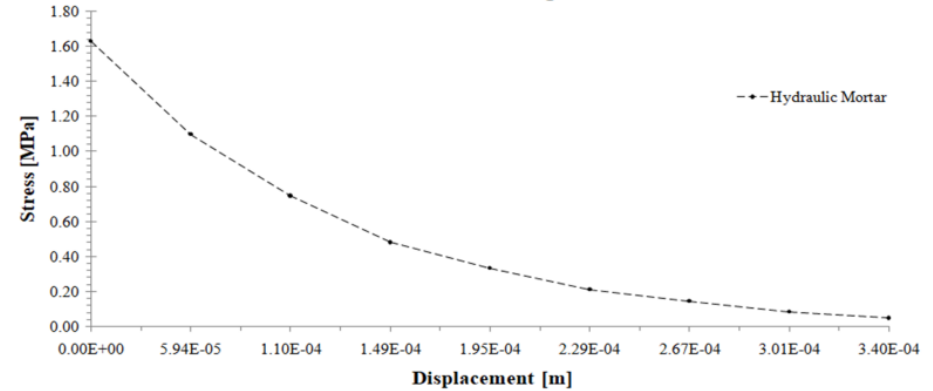
Parameters of CDP model

$\beta_d [^\circ]$	35	m	0.1	$f_y = f_{bo}/f_c$	1.16	K_l	0.667
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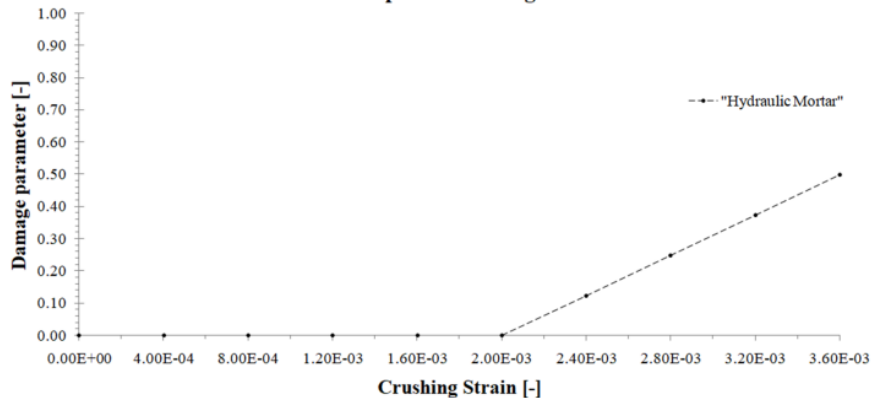
Compression hardening



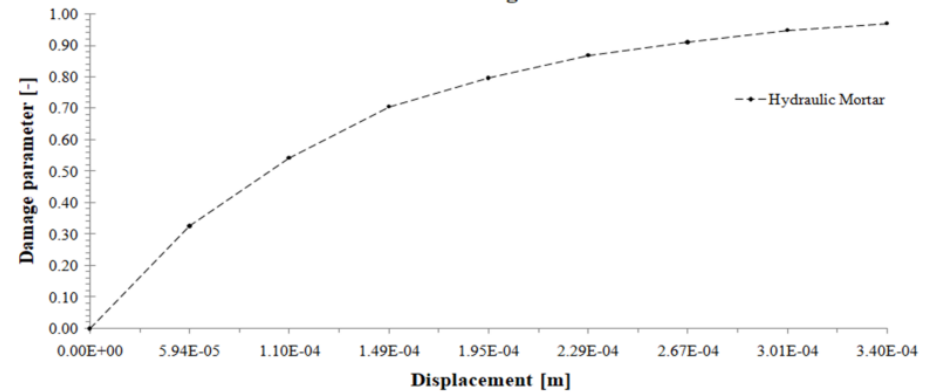
Tension Stiffening



Compression damage



Tension damage



$$d_c = 1 - \frac{\sigma_c}{\sigma_{cu}}$$

$$d_t = 1 - \frac{\sigma_t}{\sigma_{t0}}$$