S&A - Permanent staff

Patrick Bamonte
Assistant Professor

Giovanni di Luzio
Associate Professor

Giacomo Boffi
Assistant Professor

Claudio di Prisco
Professor

Matteo Colombo
Assistant Professor

Marco di Prisco
Professor

Gabriele della Vecchia
Associate Professor

Roberto Felicetti
Associate Professor

Liberato Ferrara
Associate Professor
S&A - Permanent staff

Andrea Galli
Assistant Professor

Cristina Jommi
Professor

Luca Martinelli
Associate Professor

Paolo Martinelli
Assistant Professor

Maria Gabriella Mulas
Associate Professor

Roberto Paolucci
Professor

Federico Perotti
Professor

Lorenza Petrini
Associate Professor

Donatella Sterpi
Assistant Professor
S&A – research areas

Concrete and advanced cement based materials (ACBM) and structures
- Concept, development, mechanical characterization and modelling of advanced cement based materials
- Structural behaviour of concrete and ACBM elements
- Innovative structure concept for accidental events and sustainability
- Structural assessment and retrofitting

Earthquake engineering and structural dynamics
- Engineering seismology
- Earthquake engineering
- Structural Dynamics and Wind Engineering

Geomechanics and geotechnical engineering
- Natural hazards: prediction, prevention and mitigation
- Geotechnical structures
- Geo-resources, environment and underground engineering
Concrete and Advanced Cement Based Materials

Mechanical characterization of FRC, HPFRCC, TRC

Supposed flow lines:

Slab A

- Casting direction
- 50, 150, 150, 150, 500 mm - 20 in.
- 150 mm - 6 in.
- 450 mm - 18 in.
- 200 mm - 8 in.

Frame
- Rotatable support
- Steel liner
- Brass plate

Verifying F-L
- Type B
- COD UP F
- COD MID F
- COD DW F

50 mm - 2 in.
150 mm
30 mm - 1.2 in
7 mm

DEWS L1/2-B
- Beam T2-B
- Beam T1-B
- Beam L2-B
- Beam L2-A
- Beam T2-A
- Beam T1-A
- Beam L1-B
- Beam L1-A

Slab A
- 200 mm - 8 in.
- 450 mm - 18 in.

DEWS T1/T2-B
- COD UP F
- COD MID F
- COD DW F

Slab A
- 50 mm - 2 in.
- 20 mm - 0.8 in.

DEWS L1/2-A
- Beam T1-B
- Beam T2-B
- Beam L1-B
- Beam L2-B

DEWS T1/T2-A
- COD UP F
- COD MID F
- COD DW F

Slab A
- 50 mm - 2 in.
- 30 mm - 1.2 in

Beam L2
- Beam L1
- Beam T2
- Beam T1

Casting direction
- Supposed flow lines

COD (mm)

σ (N/mm²)

0 2 4 6 8 10

0 2 4 6 8 10

0 2 4 6 8 10

0 2 4 6 8 10

COD (mm)

σ (N/mm²)

0 2 4 6 8 10

0 2 4 6 8 10

0 2 4 6 8 10

0 2 4 6 8 10

strain ε

COD (mm)

crack opening w (mm)

Slab A
- Beams L1/2

Deformation energy work of stress (DEWS)

L1-B

L2-B

L1-A

L2-A

Type B

COD UP F

COD MID F

COD DW F

DEWS L1/2-B

DEWS T1/T2-B

DEWS L1/2-A

DEWS T1/T2-A

Slab A

- Beams L1/2

- COD (mm)

- σ (N/mm²)

- COD (mm)

- σ (N/mm²)

- COD (mm)

- σ (N/mm²)
Concrete and Advanced Cement Based Materials

Concept and mechanical characterization of collapsible concrete
Concrete and Advanced Cement Based Materials

Rheological characterization of HPFRCC

Rheological Building Materials Cell

**Rheological Unit**
- paddel-shaped rotor
- specimen container with anti-wallslip serration
- cement paste or mortar \( d_{\text{max}} < 4 \text{ mm} \)
Concrete and Advanced Cement Based Materials

Early age and long term behaviour of concrete
Concrete and Advanced Cement Based Materials

Experimental characterization of HP concrete at high temperature and in residual conditions

direct-tension tests at high temperature

splitting test under sustained pore pressure

residual tests

\[
\sigma (\text{MPa})
\]

\[
\begin{align*}
20^\circ\text{C} & : f_{ct} = 90 \text{ MPa} \\
250^\circ\text{C} & \\
600^\circ\text{C} & \\
\end{align*}
\]

Tensile strength / \( f_{ct}^{20^\circ\text{C}} \)

Pressure / \( f_{ct}^{20^\circ\text{C}} \)
Concrete and Advanced Cement Based Materials

characterization of thermal properties and fire testing of small structures and protective materials

assessment of thermal diffusivity in the range 20-1000°C

small furnace (BBQ) for fire testing of panels and protective materials
Concrete and Advanced Cement Based Materials

Self healing of cementitious composites

after 1 month in water

after 3 months in water

after 6 months in water
Concrete and Advanced Cement Based Materials

Concept and mechanical characterization of cementitious composites reinforced with natural/recycled fibers

- Natural Fibers Absorb the humidity
- In case of crack the released humidity will help further hydration

Before

After 1 Month
Concrete and Advanced Cement Based Materials

Damage modelling of concrete behaviour

... vs. DIC
Concrete and Advanced Cement Based Materials

Meso-scale modeling of Alkali-Silica-Reaction (ASR) damage in concrete

Formation and expansion of ASR gel

Free Expansion, Unrest. -20 MPa, Rest. -5 mm; 0 MPa

\[ \dot{z} = -\frac{a_s(T)\omega_s}{r_w c_s z (1 - \frac{2z}{D})} \]

Development of cracking

\[ \dot{M}_i = \frac{C_0^2}{\delta^2} \exp(-\eta M_i) \left[ K_i^0 (1 - \zeta^3) D^3 \kappa_a \exp\left( \frac{E_{ai}}{RT_0} - \frac{E_{ai}}{RT} \right) - M_i \right] \]
Concrete and Advanced Cement Based Materials and Structures

- Development of equipment and setups for material and structural testing (in lab & onsite)
  - Laboratory load tests
  - In situ load tests
  - Structural monitoring
  - Fire testing
Advanced Cementitious Composites In Design and Construction of Safe Tunnels

SUPSI
University of Applied Sciences of Southern Switzerland
Concrete and Advanced Cement Based Materials ... and Structures

Advanced Solutions for Outdoor Energetic Retrofit of façade
Concrete and Advanced Cement Based Materials ... and Structures

Design of FRC retaining structure (Caslino Lab)
Concrete and Advanced Cement Based Materials ... and Structures

Development and Analysis of new cement based materials for seismic retrofitting - coupling beams

<table>
<thead>
<tr>
<th>Cases</th>
<th>R/C coupling beams</th>
<th>Pre-damage levels of RC specimens retrofitted with UHPFRC</th>
<th>Composite used to retrofit RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Plain concrete (PC)</td>
<td>PC longitudinally reinforced (LR)</td>
<td>LR + Stirrups (RC)</td>
</tr>
</tbody>
</table>

- Architrave con armatura completa
- Architrave rinforzato con HPFRC
- Architrave rinforzato con TRC
- Architrave riparato con HPFRC (1% predanneggiato)
Concrete and Advanced Cement Based Materials …
and Structures

development of Non-Destructive tools
for structural inspection and damage assessment

concrete analysis (colour, carbonation, DTA)
via a sorted sample of drilling powder

time of flight
of the drill pulses
Concrete and Advanced Cement Based Materials …
onsite assessment of damaged structures

- fire damage assessment
- delamination in floorings and tiles
- debris inspection
- modelling of fire scenario
- load/vibration tests
- residual deformation
- ultrasonic pulse transmission/refraction
- drilling resistance
- rebound hammer
- pull-out
- rebars hardness
- discoloration, chemo-physical analysis
- mobile robots for flatness and delamination survey
Earthquake engineering and structural dynamics

Seismic Hazard Assessment for critical facilities

Approaches to account for site effects in the Probabilistic Seismic Hazard Assessment
Earthquake engineering and structural dynamics

High-performance computing tools in elasto-dynamics (SPEED code, with Dept of Mathematics)

Traffic-induced vibrations

L’Aquila basin

Seismic wave propagation in complex geological configurations
Earthquake engineering and structural dynamics

Earthquake ground-shaking scenarios in large urban areas

SANTIAGO DEL CILE

Crustal model

<table>
<thead>
<tr>
<th>$Z$ (km)</th>
<th>$\rho$ (t/m$^3$)</th>
<th>$V_s$ (m/s)</th>
<th>$V_p$ (m/s)</th>
<th>$Q$ (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2.2</td>
<td>2.4</td>
<td>2400</td>
<td>4700</td>
<td>240</td>
</tr>
<tr>
<td>2.2–8.9</td>
<td>2.7</td>
<td>3200</td>
<td>5900</td>
<td>320</td>
</tr>
<tr>
<td>&gt;8.9</td>
<td>2.8</td>
<td>3450</td>
<td>6200</td>
<td>350</td>
</tr>
</tbody>
</table>

Santiago Basin

$V_s(z) = 400 + 55\sqrt{z}$

$V_p(z) = 1730 + 60\sqrt{z}$

$\rho(z) = 2100 + 0.15z$

$Q_s = 40$

~ 5 hours on FERMI using 512 cores
Earthquake engineering and structural dynamics

Guidelines for gas pipeline design

Expected earthquake induced slope displacements

Seismic hazard assessment

Pipeline response under dynamic and fault-rupture loading
Earthquake engineering and structural dynamics

The project DPC-RELUIS

Software for the design spectrum-compatible selection of real accelerograms (in cooperation with Università Federico II, Napoli)

Output management and secondary options

Target spectrum and compatibility bounds.

Site definition and reference structural code selection (Italian, European, or S5).

Limit state definition for code-based spectrum construction, or be user defined spectrum input.

Definition of bins of interest in terms of source, intensity, and site parameters.

Choice of how many horizontal components should have each record in the set.
Earthquake engineering and structural dynamics

The project DPC-RELUIS

Integrated seismic design and assessment of foundations and structures

Experimental results

Fixed-base structure

Flexible-base structure

Super structure

Foundation

POLITECNICO DI MILANO
Earthquake engineering and structural dynamics

Submerged Floating Tunnels (SFTs)

The Submerged Floating Tunnel, also known as Archimedes Bridge, serves as a promising alternative to cross sea-straits, lakes and waterways in general.

**Crossing problems:**

**Engineeringsolutions**

- Bridge
- Underground tunnel
- Immersed tunnel (I.T.)
- Floating tunnel (Archimede’s Bridge, SFT “Submerged Floating Tunnel”)

**Depth categories:**

- Shallow water
- Intermediate depth water
- Deep water
Earthquake engineering and structural dynamics

Submerged Floating Tunnels

ISSUES

• Safety assessment (e.g. flooding, fire)
• Soil-structure interaction
• Mooring system: slender members with material and geometric nonlinearity
• 3D multiple-support seismic excitation (eq)
• Seaquake: hydrodynamic pressure on the tunnel (sq)
• Control devices (at tunnel ends and in the mooring system)
Earthquake engineering and structural dynamics

Structural control of long and medium-span bridges

Medium-span bridge

Damping devices

Motion reduction

Earthquake
Earthquake engineering and structural dynamics

Bridge-vehicle dynamic interaction
Currently: bridge-human dynamic interaction

Coupled approach - Solution based on iterative uncoupled procedures

Highway RC bridge simply supported on 6 elastomeric bearings
L = 30.3 m; B = 15.48 m; s = 25 cm; $E = 29.4$ GPa

- 3-D two-axle vehicle; 7-dof's

Pavement roughness PSD
Earthquake engineering and structural dynamics

Development of ad hoc finite elements accounting for flexure-shear interaction

Force-displacement response of a RC squat column with rectangular cross-section (Arakawa et al., 1989) using fibre-flexure model (on the left), and the implemented fibre-shear model (on the right)
Earthquake engineering and structural dynamics

<table>
<thead>
<tr>
<th>Test</th>
<th>Type</th>
<th>P.G.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WN</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>Nice</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>WN</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>Nice</td>
<td>0.05</td>
</tr>
<tr>
<td>5</td>
<td>Nice</td>
<td>0.06</td>
</tr>
<tr>
<td>6</td>
<td>Nice</td>
<td>0.15</td>
</tr>
<tr>
<td>7</td>
<td>Nice</td>
<td>0.06</td>
</tr>
<tr>
<td>8</td>
<td>Nice</td>
<td>0.052</td>
</tr>
<tr>
<td>9</td>
<td>Nice</td>
<td>0.116</td>
</tr>
<tr>
<td>10</td>
<td>SF</td>
<td>0.066</td>
</tr>
<tr>
<td>11</td>
<td>SF</td>
<td>0.15</td>
</tr>
<tr>
<td>12</td>
<td>SF</td>
<td>0.132</td>
</tr>
<tr>
<td>13</td>
<td>WN</td>
<td>0.10</td>
</tr>
<tr>
<td>14</td>
<td>SF</td>
<td>1.11</td>
</tr>
<tr>
<td>15</td>
<td>WN</td>
<td>0.10</td>
</tr>
<tr>
<td>16</td>
<td>Nice</td>
<td>0.252</td>
</tr>
<tr>
<td>17</td>
<td>Nice</td>
<td>0.41</td>
</tr>
<tr>
<td>18</td>
<td>WN</td>
<td>0.10</td>
</tr>
<tr>
<td>19</td>
<td>Nice</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Response of RC wall to seismic excitation

Numerically simulated

Models for shear mechanisms

- **RUN 1**
- **RUN 2**
- **RUN 3**
- **RUN 4**
- **RUN 5**

Very low reinforcement

Ritter - Moersch truss Arch action

Compression area

Tension area

Experimental

Flexure model

Flexure-shear model

Politecnico di Milano
Earthquake engineering and structural dynamics

Development of methods based on displacement for design and assessment of bridges

Struttura reale
Earthquake engineering and structural dynamics

**IRIS reactor building**

**Computation of seismic fragility**

- **HDRB isolators**
- **non-linear hysteretic model**

The failure probability is computed according to the PEER formulation - A Response Surface is adopted to model the influence of the randomness of the structural and excitation parameters on the statistical properties of the random response - For each experimental point the random vibration problem is solved via simulation - The Response Surfaces are refined in the neighborhood of the design point - The seismic input accounts for rotational components due to kinematic soil-structure interaction and to the spatial variability of free-field ground motion.


Earthquake engineering and structural dynamics

Forensic Engineering and analysis of progressive collapse

THE COLLAPSE MECHANISM

Grey: REI 60 wall and floor still standing

Green: collapsed floor

In between: cross-section of 18-29 failed in shear

Shear failure of beams, 1° floor

Columns failure, ground floor
Geomechanics and geotechnical engineering

Multiphysics and multi-scale experimental studies of materials and models

Chemo-electro-hydro-mechanical behaviour

Small scale model for soil-atmosphere interaction

Field monitoring of water exchanges

Internal erosion and piping
Geomechanics and geotechnical engineering

Modelling the behaviour of granular materials

Ratcheting and cyclic behavior
Instability and degradation
Transition from solid-like to fluid-like materials

Analysis of underground cavities in calcareous soft rocks

Investigation and modelling of degradation processes induced by water-saturation
Formation of sinkholes
Geomechanics and geotechnical engineering

Modelling the behaviour of compacted materials of increasing activity
Retention, hydraulic conductivity, stiffness and strength

**Multiscale approach: from microstructure to the field**

**Multiphysics actions:** drying/wetting - freezing/thawing - electrical (electroosmotic) - chemical

**As compacted bentonite**
- Water retention curve for Perlite at various densities
- Simulation of pore size density function of a compacted clay

**Saturated 0.5M NaCl**
- Saturated distilled water

**Saturated distilled water (0.5M NaCl)**

**Water retention curve for compacted Boom clay**

---

**Water retention curve for**
- Permeability, hydraulic conductivity, stiffness and strength
- Simulation of pore size density function of a compacted clay

---

**Retention, hydraulic conductivity, stiffness and strength**

**Simulation of pore size density function of a compacted clay**

---

**POLITECNICO DI MILANO**
Geomechanics and geotechnical engineering

Design of special foundations for embankment on soft soils

Behavior of shallow and deep foundations subject to cyclic loads

Small scale experimental setup
Geomechanics and geotechnical engineering

Cracking phenomena in clayey soils undergoing desiccation processes

Durability, maintenance and mitigation actions for Barriers, Dykes, Embankments, Slopes
Geomechanics and geotechnical engineering

Seismic performance of earth slopes

Numerical simulation of the seismic response
Inception of landslides and displacement assessment

Impacts of boulders and granular flows on sheltering structures

Experimental and numerical analysis
Discrete element and macroelement modeling
Impulsive soil-structure interaction
Geomechanics and geotechnical engineering

Tunneling in difficult conditions

GROUND IMPROVEMENT and SOIL NAIL STABILISATION at the tunnel face
SOFTENING and SQUEEZING GROUND CONDITION

Thermo-active Geostructures

for low enthalpy geothermal energy sources

EFFECTS on SOIL TEMPERATURE and on SOIL-STRUCTURE INTERACTION

PIPE LAYOUT OPTIMISATION

Stress in a tunnel liner in squeezing conditions

Design of structural intervention measures for landslide risk mitigation

Soil thermal drift and temperature field in a thermo-active diaphragm wall