An hydraulic monitoring system on a Bridge over river Po

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F. Ballio, G. Crotti, A. Cigada, S. Manzoni, F. Inzoli
The Monitoring system location

Monitoring system is working from March 2011
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**Reference (bankfull) values:**
- Depth = 16 m
- Velocity = 4.5 m/s
- Width = 300 m
- Expected scour / degradation > 15 m
Goals of the project

1) Define the Bridge loads
   - Wind drag force
   - Water drag force
   - Traffic forces

2) Define other additional phenomena
   - Scour around pier
   - Trapped debris upstream the pier

3) Define monitoring system configuration

4) Define structural model of the pier

5) Evaluate the safety factor of the pier

6) Define the management plans
BLESS© (Bed Level Seeking System)

sedimeter (BLESS©)

Water surface

Riverbed level

PIER

echosounder
BLESS © → How does it work?

Example layout of the monitoring system

- Fiber optic interrogator
- Heater
  \[ V = \text{cost.} \]
- Data management system

Air \( T_a \)

Water \( T_{w0} \)

Sediment \( T_{sed0} \)

Stainless steel tube (3-6 mm)

Heat - shrinking

FBG sensor

3 Line wires along the fiber

level
BLESS© ➔ Sensor response

- **T** = temperature [°C]
- Power on: heating
- Time [s]

**Laboratory results**

- Sensors buried in the bed
  - heat dispersion by conduction
- Sensors in flowing water
  - heat dispersion by convection
BLESS © → Sensor response

Echo-sounder

Temperature [°C]

Level [m asl]

FBG Sensor

POLITECNICO DI MILANO
The Monitoring system configuration

- Video camera
- Infrared
- Video camera
- Control room

Flow direction:
- Remote station

Data transfer:
- Echo-sounder
- BLESS sedimeter
- Hydrometer
- Anemometer
From monitoring to safety factor

**Monitoring** ➞ **Loads** ➞ **Structure** ➞ **Safety factor**

- **Echo-sounder**
- **Hydrometer**
- **Video camera**

**Riverbed elevation (m asl)**

- May 2012
- River elevation (m asl)

**Wind Direction**

- S
- E
- N
- W

**Wind Average Speed**

- Wind Gust

**Riverbed elevation (m asl)**

- 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

**River elevation (m asl)**

- 0 2 4 6 8 10 12 14 16 18 20 22 24

**Wind velocity (km/h)**

- 0 2 4 6 8 10 12 14 16 18 20 22 24
From monitoring to safety factor

Monitoring$\rightarrow$ Loads$\rightarrow$ Structure$\rightarrow$ Safety factor

Wind $\rightarrow$ $F_w = f(V_w, T)$

Water $\rightarrow$ $F_{wa} = f(h_{wa}, D)$

Wind drag force (pier 30) (a)

- $V_{wind}$ (m/s)
- Force (kN)
- $T = 0$
- $T = 1$
- $+35\%$ $T = 1$

Water drag force (pier 30) (b)

- $h_{water}$ (m)
- Force (kN)
- $D = 0$
- $D = 1$
- $+260\%$ (max)
From monitoring to safety factor

Monitoring $\rightarrow$ Loads $\rightarrow$ Structure $\rightarrow$ Safety factor

Wind $\rightarrow$ $F_w = f(V_w, T)$

Water $\rightarrow$ $F_{wa} = f(h_{wa}, D)$

(Water $\rightarrow$ $F_{wa} = f(h_{wa}, D)$(Pier weight is also included)

$F_w = f(V_w) , M_V = f(T)$

Weight $\rightarrow$ $F_v = f(T), M_V = f(T)$

Deceleration $\rightarrow$ $F_{vd} = f(T), M_{vd} = f(T)$

Total actions $= f(V_w, h_{wa}, d_s, T, D)$
From monitoring to safety factor

Monitoring → Loads → Structure → Safety factor

28th Oct - 7th Nov 2012 > SAFETY FACTOR

Safety Coefficient

28th Oct - 7th Nov 2012 > SAFETY FACTOR

Safety Coefficient

10/28/12 10/29/12 10/30/12 10/31/12 11/01/12 11/02/12 11/03/12 11/04/12 11/05/12 11/06/12 11/07/12

2.80 2.76 2.72 2.68 2.64 2.60
... conclusions and next steps

GLOBAL TARGET: ACHIEVED (system works!)

CRITICALITIES: BED LEVEL
- we cannot robustly forecast it
- measurements not standard

ONGOING VALIDATION
From 2011 to 2013: bed level

ONGOING VALIDATION
... conclusions and next steps

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ONGOING VALIDATION

SEE ALSO OUR POSTER
From 2011 to 2013: focus on Echo-sounder
From 2011 to 2013: parameters → safety factor

- **Borgoforte 2011 >> 2013**
  - Water level (Hydrometer)
  - Riverbed level (Echo-sounder)
  - Wind gust
    - Same direction of water flow
    - Opposite

- **Safety Coefficient**
  - From 2011 to 2013: parameters → safety factor
From 2011 to 2013: parameters → safety factor

Borgoforte Hydrometer & Echosounder - ZOOM

Water level (Hydrometer) - riverbed level (Echosounder)

Borgoforte Anemometer - ZOOM

Wind gust: +: same direction of water, -: opposite

Safety Coefficient - ZOOM

Safety Coefficient: 2.60 to 2.80