Advanced Numerical Modelling for Slow Landslide Analyses through the Effective Integration of SBAS-DInSAR and in situ Observations: the Case Study of Ivancich Landslide (Assisi, Italy)


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The case study: Ivancich landslide

The landslide site has been extensively investigated through in-situ surveys. In particular, deep boreholes and inclinometer measurements are available, providing information on the geological setup and geotechnical properties of the landslide body.
C- and X-Band SAR Datasets

91 Descending ERS-1/2 and 39 ENVISAT (130 scenes) 1992-2010

39 Descending CSK December 2009 – February 2012
1992-2010 ERS-ENVISAT Results

\[ \sigma = 0.5 \text{ cm} \]
C- and X-Band Result Comparison
C- and X-Band Result Comparison

Mean velocity [cm/yr]

>1

<1

San Nicola

Assisi

Assisi

CSK

Ivancich

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FEM Modelling Inversion: Flow Chart

**FIELD DATA INPUT**
Deformation Time Series (DInSAR & Inclinometric Data)

**NUMERICAL MODEL INPUT**
- Slope geometry
- Geological setting
- Boundary conditions
- Physical and elastic parameters (Density, Young’s Modulus, Poisson ratio)

**Forward Numerical Model**

**OPTIMIZATION PROCEDURE**
Genetic Algorithm

**BEST-FIT SOLUTION AND PARAMETERS**
Landslide Kinematical Evolution: 2D FEM Modeling

SS’: Longitudinal Section of the Landslide

4 Inclinometers (103, 113, 117, 202) recorded in the 1998-2009 time period

Detailed Geological and Geotechnical Information
Inclinometric Data
Time Interval: 1999 – 2008

Limestone
Arenaceous Marl
Calcareous Marl
Landslide debris

Thickness: 2 m
Thickness: 1.5 m
Thickness: 1 m
Thickness: 1 m

Depth [m]
Incremental Displacement [mm]
Incremental Displacement [mm]
Incremental Displacement [mm]
Incremental Displacement [mm]

0 m 100 m

Shear Band

103
117
113
202

Thickness: 2 m
Thickness: 1 m
Thickness: 1 m

Incremental Displacement [mm]
Incremental Displacement [mm]
Incremental Displacement [mm]
Incremental Displacement [mm]
Boundary conditions

Legend
- Limestone
- Arenaceous Marl
- Shear band
- Landslide debris

Fixed Parameters

$\alpha_n$ unknow parameters

Newtonian Viscosity
Creep Rate

Roller constrain

Fixed constrain
2D time-dependent Finite Element Model

Stages of modeling

Step 1: assignment of the slope initial stress state - gravity loading procedure, ground water level consistent with piezometer data

Step 2: time-dependent analysis - Physical model analysis

2D FEM mesh with refinement along the shear band layer

Number of nodes: 21800
Maximum dimension of mesh elements: 400 m
Minimum dimension of mesh elements: 5 m
Best-Fit Solution: Model vs ERS/ENVISAT data

Pixel 1

Pixel 2

Pixel 3

Pixel 4

Pixel 5

Pixel 6

- SAR data
- Newtonian model
- Creep model
Best-Fit Solution: Model vs Inclinometric data

- Inclinometric data
- Newtonian model
- Creep model

Displacement (cm) vs Time [yr] graphs for different models and data types.
Further FEM Exploitation: 2D Temporal Behavior

Amplitude Deformation Velocity

Distance [m] vs. Height [m]

Displacement [cm]
Cosmo Sky-Med Data
Time Interval: 2010 - 2012

SBAS DInSAR measurements superimposed on geomorphological map

- Yellow: Debris
- Light Blue: Colluvial
- Light Green: Substratum

Active | Quiescent
3D time-dependent FEM

Elements mesh size:
500 [m] – 5 [m]
Model vs Cosmo Sky-Med data: Spatial comparison
3D FEM Modeling Results
3D FEM Modeling Results

Inclinometer 117

Displacement [cm]
The effective exploitation of the multi-sensor and multi-scale SBAS-DInSAR algorithm properly combined with in-situ measurements and geological information, to investigate the temporal behaviour of mass-movement has been presented.

FEM modelling approach ensures to discriminate the causative driving forces responsible of the observed slow kinematic process that governed the landslide evolution. More specifically, by using the numerical approach has been possible to select the more suitable physical scenarios considering the geological and geotechnical available for the considered case study.