README – Data Acquisition and Database Structure

This document provides a concise overview of the methodologies adopted for data acquisition, which supported the analyses presented in the publication *“Estimating friction angle in partially saturated soils from CPT: application to river levees.”* Furthermore, it illustrates the structure of the database compiling the data obtained from the various field and laboratory investigations.

Field investigation (CPTs and Boreholes)

Field investigations were conducted at three levee segments located in the Emilia-Romagna and Veneto regions of northern Italy. The tested segments were situated along the Grizzaga River and the Panaro River (both in the province of Modena), and along the Tagliamento River (in the province of Venice).

CPTu tests (EN ISO 22476-1/12) were performed along the levees of the Grizzaga, Panaro, and Tagliamento Rivers. Each CPTu test was correlated with a geognostic borehole (UNI EN ISO 22475 / EC7-2), from which undisturbed soil samples were collected and subsequently analyzed and characterized through laboratory testing.

Dry drilling was carried out above the groundwater table, and soil samples were obtained using a piston sampler (Osterberg type).

At the first site (Grizzaga River), the CPT test considered was GCPT2, located near the borehole GS1.
At the second site, along the Panaro River, two CPTs (PCPT4 and PCPT5) and two boreholes (PS1 and PS2) were performed.
At the third site, located along the Tagliamento River, the investigation campaign included eight CPTs (TCPT2, TCPT3, TCPT4, TCPT5, TCPT7, TCPT11, TCPT12, and TCPT18) and eight boreholes (TS2, TS3, TS5, TS6, TS7, TS9, TS10, and TPS7).

Laboratory testing on samples

The collected undisturbed samples were classified following the Unified Soil Classification System (USCS) standards. Grain size distributions were performed using mechanical sieving and hydrometer tests (UNI CEN ISO/TS 17892-4). Additionally, shear tests were carried out to determine the friction angle of the collected, in order:

- on the samples collected at Grizzaga river levee, ring shear strength tests (RSS) (UNI CEN ISO/TS 17892-10) were performed;
- on the undisturbed samples collected along the Panaro river levee, triaxial test and direct shear tests were conducted: isotropically Consolidated Undrained Triaxial test (Tx CIU) (UNI CEN ISO/TS 17892-10) on PS1-C1, Direct Shear test (DS) (UNI CEN ISO/TS 17892-9) on samples PS1-C2 and PS1-C4, and isotropically Consolidated Drained Triaxial test Tx CID (UNI CEN ISO/TS 17892-10) on samples PS1-C3, PS2-C3, and PS2-C4;
- on the undisturbed samples collected on the Tagliamento River site, isotropically consolidated Tx CIU tests were performed.

As is customary, all tests were conducted at three different levels of confining stress. However, for the determination of the peak friction angle, only the test consolidated at the confining stress closer to the in-situ stress condition was considered, assuming zero cohesion.

Experimental Soil Water Retention Curves (SWRCs) determination

For the soil samples collected from the Grizzaga and Panaro river sites, experimental SWRCs on undisturbed samples were available for each soil type. Experimental determination of SWRCs was carried out through two types of laboratory tests. The first was performed using the Ku-pF apparatus (Umwelt-Geräte-Technik GmbH, Müncheberg, Germany), which allowed measurement of the soil water retention curve (SWRC) from saturation (0 kPa) down to the lower limit of tensiometer readings (approximately –70 kPa). For higher suction values,

measurements were performed using the WP4C dewpoint potentiometer (METER Group, Inc., Pullman, WA, USA). The WP4C provides the total water potential as the sum of the osmotic and matric potentials. The osmotic potential was estimated from the electrical conductivity (ECe) of the saturated paste extract, and the matric potential was obtained by subtracting the osmotic component from the total water potential.

Data repository contents

The folder **"RAW DATA.zip"** contains the database of data collected during the investigation period, organized into the following subfolders:

- **Boreholes:** contains all borehole logs in PDF format, organized by river.
- **CPTs_location:** includes a kmz file showing the locations of the investigation points (CPTs and boreholes).
- **CPTs_results:** organized in subfolder by river, contains Excel spreadsheets, including the following parameters: depth (z), cone tip resistance (q_c), sleeve friction (f_s), pore pressure (u), geographic coordinates (WGS-84) for each test, and groundwater depth.
- **Experimental_SWRCs:** contains Excel spreadsheets organized by river, reporting the experimental Soil Water Retention Curves (SWRCs). The data include suction (s), volumetric water content (ϑ), degree of saturation (S_r), saturated hydraulic conductivity (ksat), residual and saturated volumetric water contents (ϑ_r and ϑ_s), and the fitting parameters of the modelled curve according to the Van Genuchten model (a and n).
- **Grain_size_distribution:** contains PDF files organized by river, reporting the grain-size distribution curves obtained for each undisturbed soil sample.
- **Laboratory_tests:** organized in subfolders by river, containing Excel files—one for each undisturbed sample—reporting the interpretation of residual shear tests for the Grizzaga River, and direct shear and triaxial shear tests for the Panaro and Tagliamento Rivers.

Data Format

All tabular data are provided in **Microsoft Excel** (.xlsx) format.

Geographical data are provided in **KMZ** format (WGS-84 reference system).

Plots and figures are provided in **PDF** format.