Geotechnical characterization of the Florence (Italy) soils

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ABSTRACT

This paper deals with the geotechnical characterization of the Florence (Italy) subsoil. On the base of 1932 stratigraphic log from drill-holes, and the related available geotechnical lab tests, we performed a statistical geotechnical characterization of the Florence subsoil, according to the geological allostratigraphic and litotechnical units defined by the Neogene evolution of the Florence intermountain sedimentary basin. It resulted Early Pleistocene palustrine and alluvial deposits; Late Pleistocene the Arno River filled the valley with river bed deposits; in Holocene all the area was covered by fluvial and alluvial deposits. The geotechnical statistical analysis performed outline different values in the main parameters of the three units, each one subdivided into granular and cohesive. In addition, the Vs display different referencing values for each unit. Statistical analysis were made according to the indication of Eurocode 7 and Italian rule NTC 2008.

Keywords: Florence, subsoil, geotechnical characterization, Vs

1 INTRODUCTION

Since 2001 the Dep. of Earth Science of the Florence University and the Geological Office of the Florence Municipality are working on a join project regarding the achieving of the geological knowledge of the Florence are. In this frame, the litostratigraphic logs of the 1932 drill-holes available for the Florence area had been collected and implemented into a geodatabase (GDB) connected with a GIS of the Florence area (coordinate system: Monte Mario Italy 1 – ESRI® ArcMapTM 10.0, copyright © 1999–2010 ESRI Inc.).

The regional geological setting of an area and its recent evolution and climate environment are responsible for its soil types and assemblage. In turn, this soil setting plays an important role in ensuring foundation stability and durability for buildings. This aspect is of a special importance for a worldwide well-known city as Florence, which historical city center was declared Human Cultural Heritage by UNESCO in 1982.

2 GEOLOGY

Florence is settled in an inner sedimentary basin of the Northern Apennines that resulted from the Late Pliocene activity of the Fiesole faults. The basin was infilled by Early Pleistocene palustrine and alluvial deposits; in the middle Pleistocene, the Florence area, due to the role of transversal faults, underwent to uplift and the Arno River eroded a valley in these deposits. Since Late Pleistocene, the Arno River filled the valley with riverbed deposits; in Holocene the whole area was covered by fluvial and alluvial deposit (Briganti et al 2003).

According to this geological history, the deposits of Florence basin can be grouped into three UBSU (ISSC 1994): the Synthem of the Basin (BS); the Ancient Arno River Deposits (AD); the Recent Arno River Deposits (RD) (Coli & Rubellini 2013) (Fig.1).
3 GEOTECHNICAL DATA

In this geological frame, each log has been interpreted in terms of UBSU (ISSC 1994) and USCS (ASTM: D2488-84 and BS 5930:1981), with a main subdivision into cohesive or granular. All these data were implemented into a GIS (ESRI® ArcMapTM 10.0 - Copyright © 1999-2010 ESRI Inc.) in order to manage all the features in 2D and 3D (ESRI® ArcSceneTM 10.0 - Copyright © 1999-2010 ESRI Inc.).

That let possible to refer the available lab data to the several UBSU/USCS combination from which the samples comes:

- RD cohesive; RD granular,
- AD cohesive; AD granular,
- BS cohesive; BS granular.

Lab data are only available for the most recent 354 of the 1936 stratigraphic logs drilled in the Florence area (Fig.1), but they largely cover all the soil units of Florence. Despite that, all the defined geological units are well represented by the reliable data.

Of course, we have taken these lab data “as they are” because they derive from different laboratories, projects, and years and we had not have any chance to made a critical control on their laboratory runs.

The data collected could allow also to give information at the level of the single USCS unis (LS, LP, ..., GW, GP, ...) for each geological Unit, but due to the aim of this paper we decided to stay at this level of information.

The geotechnical data we taken into account were:

For all soil units
- Volume weight,
- Grain size,
- Vs.

For granular soil units
- Calcareous/siliceous clasts ratio,
- $\phi'$ from NSPT data.

For cohesive soil units
- $c'$ and $\phi$.
- Activity and plasticity.

4 STATISTICS

If possible, the main geotechnical parameters of the BS, AD and RD soils in their two main groups: cohesive and granular were statistically analyzed because:

a) the data of characterization we present must be used for a general characterization for planning purposes and not for a specific design of building or infrastructures, for this purpose in situ specific new investigations must be made,

b) Eurocode 7 and the new Italian rules (NTC2008) require referring the in situ data into a statistical distribution in order to choose the appropriate data for the design.

Statistical analysis have been done by means of self-made macro of Excel (© Microsoft) which for each couple of lab data creates, by means of the Montecarlo simulation, ten data and then made a clustering density map of all these data. This procedure allows to create a well-numbered population for the statistical analysis and to smooth isolated clusters and outliers.

Single data were statistical analyzed in terms of Gaussian distribution around the average value.

Vs data were analyzed as weighted average considering the lengths of the soil unit drilled and measured in terms of Vs in each down-hole.

5 ANALYSIS

The main results for each geotechnical parameter are here reported, in Appendix there are the diagrams of the analysis performed for the several Florence soil units and geotechnical parameters.

5.1 Volume weight

The mean values, and their standard deviation, for the Volume weight of the different soil units, are reported in Table 1. Consistence and persistence of the mean values result through all the soil units (Fig.2).

| Soil unit | cohesive SD | granular SD |
|-----------|-------------|-------------|
| RD        | 20.5 1.9    | 20.1 2.0    |
| AD        | 20.0 1.2    | 20.4 1.3    |
| BS        | 20.1 0.9    | 20.3 1.0    |

Gaussian distribution VW cohesive
5.2 Grain size

Cohesive soil units (Fig.3) display similar grain size clustering in the boundary area among the fields of clay/clay-loam/silty-clay/silty-clay-loam. BS cohesive soils appear more clayey and RD cohesive soils appear more silty.

BS granular soil units (Fig.4) are poorly sorted, whereas RD granular soil are better sorted due to they derive from river bed deposits.
5.3 $V_s$

$V_s$ anchorage data (Fig.5) result from the analysis of 36 down-holes, these down-hole drilled all the soil units. For each soil units drilled segments it was calculated the weight average $V_s$; therefore it was possible to infer the anchorage velocity for each soil units.

To be noticed the relative high velocity of the AD soil units.

5.4 Calcareous/siliceous ratio

On the base of a lithological analysis of the clasts retained by a 3 mm sieve it was possible to define the calcareous/siliceous ratio of the granular deposits.

Despite their membership, about 80% of the clasts are of calcareous composition (Fig.6). This figure well reflects the rock composition of the closer area of the catchment basin upstream Florence.

5.5 Granular soils: $\phi'$ from NSPT data

For the $\phi'$ data related to the granular soil units we analyzed the $\phi'$ values reported in the lab data as deriving from the NSPT in situ tests.

We have no idea about which of the several relations between NSPT data and $\phi'$ was used for each of the lab data, despite that the date (Tab. 2) results consistent and very close to the mean values (Fig.7).

| Soil unit | mean $\phi'$ | Stand.Dev. $\phi'$ |
|-----------|--------------|-------------------|
| RD        | 38°          | 7°                |
| AD        | 40°          | 6°                |
| BS        | 44°          | 8°                |
5.6 Cohesive soils: $c'$ and $\phi'$

The $c'$ and $\phi'$ couples of data for the cohesive soil units were increased by means of the Montecarlo simulation and statistically analyzed as cluster distributions (Fig.8). The results are similar for each cohesive soil units: $c'$ values range from about 8 kPa to 55 kPa, $\phi'$ values range between 20° to 45°.

5.7 Activity

Soils activity was analyzed by increasing lab data with the Montecarlo simulation and then statistically analyzing them as cluster distributions on the Activity Chart (Fig.9).

Figure 8. Gaussian distribution of the $\phi'$ as resulting from the NSPT data for granular soil units. BS= Basin Synthem, AD= Ancient Deposits, RD = Recent Deposits.

Figure 8. Statistical density distribution of the $c'$ and $\phi'$ couples of data for the cohesive soil units.

The results are similar for each cohesive soil units: $c'$ values range from about 8 kPa to 55 kPa, $\phi'$ values range between 20° to 45°.
BS and RD clays fall in the HE field, instead AD clays range from ME up to a main cluster in the VHE field. All clays are around/below the Illite line.

5.8 Plasticity
Soils activity was analyzed by increasing lab data with the Montecarlo simulation and then statistically analyzing them as cluster distributions on the Plasticity Chart (Fig.10).

Both BS and AD soils mainly fall in the High plasticity field in the area of CH soils; RD soil display a Medium plasticity and fall in the field of the CI soils.

6 CONCLUSIONS
The main result to outline is a general uniformity of the values among the different soil units. That can be correlate to the fact that the regional geological and geomorphological context in which frame those sediments were deposited had been quite uniform:
- an inner sedimentary basin with no high energy events,
- very shallow palustrine basin,
- no large energy changes in the incoming river/creeks,
- persistence during the time of the same type of sediment eroded in the basin tributary catchment basin.

In summary, the soils of Florence are good soils with good to very good geotechnical features, which allowed the building of important monuments on a safe ground and has been ensuring their stability through the centuries.

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