Implementation of the AGS geotechnical data transmission format: the Brazilian experience

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ABSTRACT

In the technology age, when cloud computing and artificial intelligence are prominent, the Association of Geotechnical and Geoenvironmental Specialists (AGS) digital data format gains its greatest importance. This paper presents a case study using the AGS digital transmission standard for geotechnical investigations in Brazil. The AGS data transmission standard developed in the United Kingdom is discussed with reference to reporting qualities in terms of flexibility and robustness. Next, two sectors in Brazil that started using the AGS format before it was officially implemented in the country are presented. It includes highways operated by private companies and academic researchers focused on the application of Artificial Intelligence and Data Science techniques to a national geotechnical investigation Big Data. Hence, the urgent need to implement a standardized format for geotechnical data transmission; as well as the opportunities that it presents, such as the integration with Building Information Modelling (BIM) software. It includes information for maintenance, operation of infrastructures and the development of automated geotechnical correlations. In conclusion, the case study indicates that, if the digital demands are not met by the official standardization in Brazil of geotechnical data transmission, private and scientific researchers may force this to occur through widespread use.

Keywords: AGS format, geotechnical data, data exchange, regulation

1 INTRODUCTION

In the last few decades, computer technology has profoundly affected all human activities, with significant impacts on communication, transmission, and storage of data. Engineering projects have gradually evolved from manual processes to Computer-Aided Design (CAD). Analysis is routinely performed in highly sophisticated data environments, such as Geographic Information Systems (GIS) or BIM.

It is notable that despite geotechnical information being obtained from costly drilling and laboratory operations, in most cases, the data is poorly documented and curated. Moreover, many projects are becoming more complex, and increasingly large volumes of geotechnical investigation data are produced which require geotechnical practitioners to spend more time and effort to assess and employ this information (Zimmermann et al., 2006). Due to the complexity of these projects, many entities share the acquisition, set up, usage, curation, and presentation of geotechnical information as presented in Table 1.

Despite the existence of standardized formats for transmitting geotechnical data, there are still few countries that have regulations or standards that require their application. Instead of focusing on the difficulties of implementing a geotechnical information transmission standard, this article aims to highlight the opportunities that are being envisioned by those who have already adopted this method of data collection and use. To demonstrate the effectiveness of such a system, a case study is presented on how the Brazilian geotechnical community has started using the format developed by the Association of Geotechnical and Geoenvironmental Specialists (AGS) without official regulations being implemented.

Table 1. Geotechnical entities involved in site investigation and their usage. (Mokarram 2010)

Data usage types	Project Engineer	Field Engineer	Driller	Lab Technician	Data Owner (Client)	Data User (researcher analyst)	Public Agencies	Private Agencies
Generating Data								
Assembling Data								
Utilizing Data for Design/Calculation								
Archiving Data								
Reporting Data								

2 BACKGROUND

2.1 Geotechnical data transfer formats

2.1.1 General

A brief description of the Geotechnical Data Transfer Formats will be given and is not intended to be exhaustive. Two of the most successful efforts that are publicly available for practical application are AGS and DIGGS.

2.1.2 AGS Format

In the early 1990s, geotechnical professionals in the United Kingdom realized the need to standardize digital information from soil surveys and tests and proposed the AGS data transmission format in 1991. It was one of the first noticeable data representations for geotechnical information and is still the most successful information release format accepted by the geotechnical community. Some of the key features are: American Standard Code for Information Interchange (ASCII) text file format, data dictionary, data groups and identifiers, and units. (Mokarram, 2010)

Currently, the AGS format is in version 4.1.1 and is compatible with numerous sophisticated modelling software, including AutoCAD Civil3D Geotechnical Module and some of the Building Information Model (BIM) design software already available for professional usage. (AGS, 2022) Geotechnical interpretation software such as gINT, Rockworks, CPT-Pro and HoleBASE are compatible with AGS.

2.1.3 DIGGS Format

On the other hand, the Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) format began development in 2005 through the joint United States effort of the Federal Highway Administration (FHWA) and the Ohio Department of Transport (DOT) with support from universities and industrial partners. This format has an eXtensible Markup Language (XML) schema and Geography Markup Language (GML) compliant data dictionary. The first DIGGS version 1.0.a was published in 2008 and the most current production version 2.5.a was published in 2020 (Merklin, 2016).

It is, however, understood that DIGGS is a very complex format compared to AGS and its initial versions had many structural inconsistencies and validation problems (Mokarram, 2010).

2.2 Benefits of geotechnical data interchange

The use of a standardized format for transmitting information is important to minimize errors in data re-entry of values, reduce risks, and maximize efficiency in geotechnical assessments. For example, single data entry mitigates errors during information transcription; data entered at the source is available throughout the project lifecycle; there is assurance that the information is consistent and can be used in a variety of applications (Malanconi et al. 2018).

Deaton (2018) summarizes that the application of either geotechnical information formats (either AGS or DIGGS) provides financial benefits to all involved parties: Owner, Consultant and Contractor. Deaton (2018, p. 5) stated that "(…) the typical consultant is re-inputting subsets of the same data between 10 and 15 times per project.". Hence, all parties are likely to reduce risk by eliminating vast amounts of data re-entry and more time can be spent performing engineering design assessments versus simply reinputting the same data.

In our current technological age, having geotechnical information in a data exchange format means organizations can use past data as well as combine all types of geotechnical information from boreholes, laboratory testing and in-situ testing together in a practical query process for more advanced analysis, visualization and even data mining applications (Wang et al., 2020).

A little-discussed advantage of using a standardized information exchange format is the quality gain in the structured organization of data. The most current version of AGS is made up of dozens of groups and headings for different types of field and laboratory tests.

For example, the group table that refers to the General data of a Static Cone Penetration Tests (SCPG) campaign has specific fields for the physical description of the tool, nominal rate of penetration, filter material, level and origin of groundwater with additional environmental fields. Although the CPT test is usually presented with a large volume of information in its reports, it is common for suppliers to not record the geometric dimensions of the cone or filter material in their reports. Rarely do companies record how the groundwater used in the interpretation of the test was obtained. Moreover, the interpreted data in AGS are registered in another group table, called Static Cone Penetration Derived Parameters (SCPP), in which the organization that carried out this evaluation should also be input.

Finally, both AGS and DIGGS formats are dynamic products, with constant development and updates. In particular, for the AGS format, Group tables and Headers disclosed in their Data Dictionary are not limiting. Each user can add new fields that they deem relevant, as long as they are duly documented in the transmitted file. This makes the format versatile and amendable to best practices that have not yet been registered in the current version of the data exchange format as well as new geotechnical tests still to be invented.

3 CASE STUDIES

3.1 Highway concessions

The Brazilian Federal Decree number 10.306, 2nd April 2020 established the use of Building Information Modelling (BIM) in the direct or indirect execution of engineering works and services carried out by agencies and entities of the federal public administration (Brazil, 2020). The implementation of the BIM system was divided into three phases. The first being valid from 1st January 2021, for the structural, hydraulic, heating, ventilation and air conditioning and electrical disciplines, the extraction of schedule of quantities and the generation of graphic drawing documentation. The other phases are applicable from 2024 and 2028 and progressively increase the use of the tools and capabilities of BIM models for engineering projects related to federal public administration.

Unfortunately, the implementation of this decree was poorly planned by the government, which did not analyze what measures would need to be taken to ensure that the implementation of BIM models would be full and efficient. One of the parts not evaluated by the federal regulation was how companies would handle geotechnical information in a BIM environment. Proof of this is that two other federal decrees, decree number 9,377 of May 17, 2018, and decree 9,983 of August 22, 2019, were published to implement BIM models but are now invalid since they were replaced by the most current decree (Brazil, 2018; Brazil, 2019).

Knowing the importance that geotechnical information has to the safety and cost of national roads, the private companies that currently operate several road concessions in Brazil united to evaluate which data transmission standard should be adopted by the sector. This evaluation took place through the formation of the AGS Brazil Group (www.padraoags.com.br) in 2018 (Malanconi et al., 2018).

It is noteworthy that the AGS Brazil Group initiative brought together highway concessionaires, geotechnical investigation companies, geotechnical engineering designers and engineering management companies. More than disseminating and adapting the British AGS standard to the Brazilian culture and custom of geotechnical investigation, the AGS Brazil Group has published 4 open-access guidelines for carrying out geotechnical investigations. These guidelines layout:

1) how to specify a schedule and planning of an investigation campaign, including stoppage criteria to be used during drilling,
2) the procedures that must be followed in the execution of the test, including the measurement of coordinates with precision GPS equipment and the photographic record of the test,
3) ways of describing the investigation results, in particular the geological-geotechnical classification of the samples, and
4) delivery of survey results in AGS digital format to the customer.

The group managed to go beyond the initial objective of disseminating the format of electronic transmission of geotechnical information and also published high-quality guidelines based on standard practices in Brazil.

These practices disclosed by AGS Brazil Group contribute to the reliability of geotechnical information, add value to the maintenance stage of the road project (also called 7D of BIM modelling) and can generate a geotechnical database of geotechnical information for the federal government regulatory agency.

It is noticeable in Figure 1 that the recommended photographic record of all samples for each Standard Penetration Test (SPT) in the AGS Brazil Group guideline adds accountability to a geotechnical investigation that follows it.

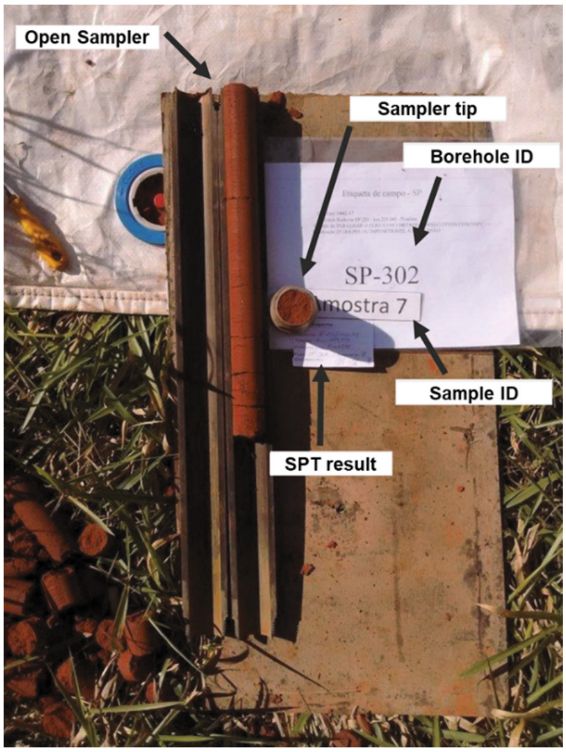

Figure 1. Photographic record of samples during boreholes (AGS Brazil, 2018)

3.2 Scientific Research

In 2018, the geological-geotechnical investigations Big Data startup iSondagens began operating in Brazil aimed at academic research usage. This initiative was inspired by existing geotechnical investigation databases throughout the world, such as DINOloket (Netherlands), GeoIndex (Great Britain), New Zealand Geotechnical Database (NZDB) and InfoSolo (Portugal) (Yanez and Reis, 2019).

By 2021, iSondagens managed to assemble over 1 million geotechnical tests from historical and present boring companies, mostly comprised of SPT boreholes. Figure 2 presents the location of the tests in the Metropolitan Region of São Paulo.

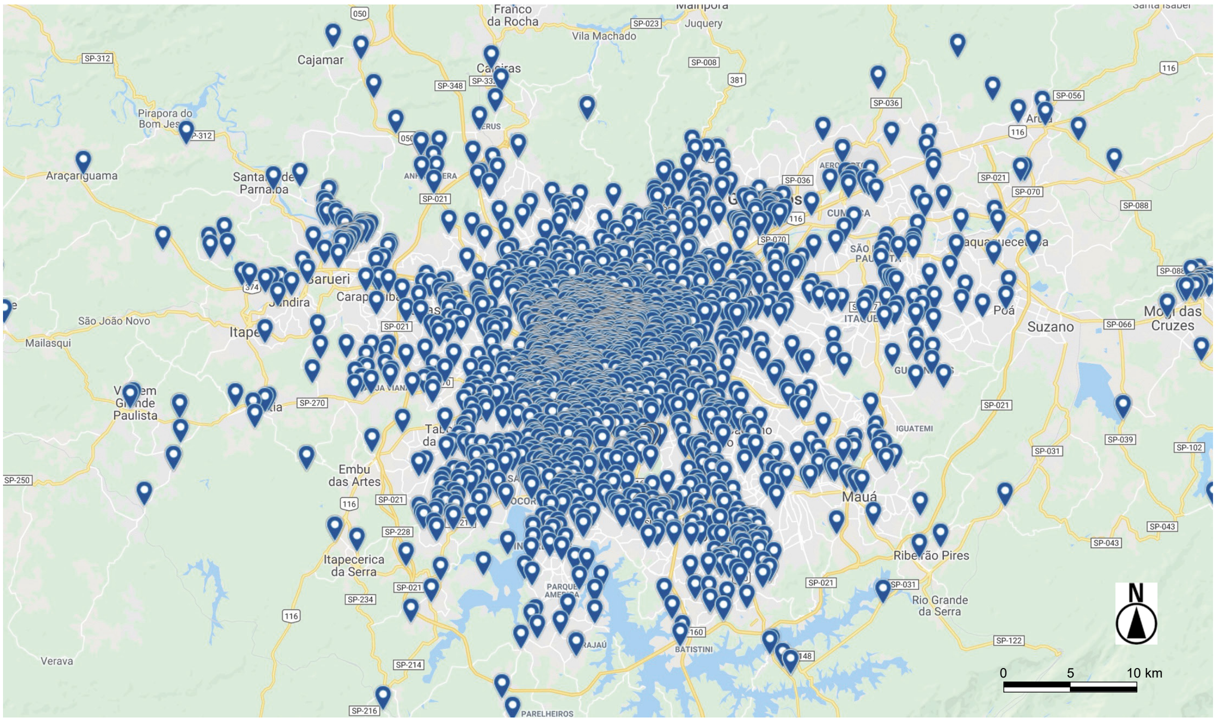

Figure 2. Map of curated by iSondagens historical boreholes at the Metropolitan Region of São Paulo (Yanez and Reis, 2019)

The Brazilian geotechnical investigation industry is particularly interested in Big Data. It is estimated that 6 million meters of boreholes are performed per year for residential construction alone.

One of the challenges faced by iSondagens was the organization of historical boreholes carried out before the publication of the first Brazilian norm for SPT in 1979. According to Yanez and Reis (2019), as the execution of penetration testing in Brazil started in 1939 by the Instituto of Technological Research of the State of São Paulo (IPT-SP), 40 of the current 83 years of geotechnical investigation history in Brazil were carried out without an established standard. This means that during the 1970s there were 3 different samplers for the execution of penetration tests: the sampler developed by IPT-SP itself, the sampler from the Geotécnica company (named Mohr-Geotécnica) and the Raymond sampler, popularized by the famous 2nd edition of the book by Terzaghi and Peck, Soil Mechanics in Engineering Practice in 1968.

The database is composed mainly of historical tests and uses the AGS format expanded to list the aforementioned samplers. For that purpose, information from tests from different samplers could be grouped and interpreted through a simple conversion algorithm based on the existing correlations for these samplers presented in Table 2.

Table 2. Correlations for soil compaction and consistency based on Brazilian historical penetration samplers (Belicanta, 1998 apud Yanez and Reis, 2019)

Soil type	**Relative Density / Consistency**	**IPT Sampler $\emptyset_e$ = 46 mm $\emptyset_i$ = 38 mm**	**Mohr-Geotécnica sampler $\emptyset_e$ = 41 mm $\emptyset_i$ = 25 mm**	**Raymond sampler (SPT) $\emptyset_e$ = 51 mm $\emptyset_i$ = 35 mm**
		Blow count		
Sand and Silty Sand	Very loose	≤ 2	≤ 4	< 5
	Loose	3 – 5	5 – 8	-
	Medium	6 – 11	9 – 18	5 – 10
	Dense	12- 24	19 – 41	11 – 25
	Very dense	> 24	> 41	> 25
Clay and Silty clay	Very soft	< 1	< 2	-
	Soft	1 – 3	2 – 5	< 4
	Stiff	4 – 6	6 – 10	4 – 8
	Very stiff	7 – 11	11 – 19	8 – 15
	Hard	> 11	> 19	> 15

Legend: $\emptyset_e$: External diameter
$\emptyset_i$: Internal diameter

4 DISCUSSION AND CONCLUSIONS

The Brazilian geotechnical practice has been breaking some paradigms in geotechnical investigations. The article aimed to bring some pioneering case studies to the Brazilian scenario.

As presented in the case studies (Malanconi et al., 2018; Yanez and Reis, 2019), the regulation of a data transmission format brings benefits in terms of quality control and quality assurance. These benefits go beyond the mitigation of data re-entry errors, through recommended reliable and verifiable executive procedures and also provide supplementary information that is rarely presented (for example, the origin of the groundwater level and the filter material in CPT).

Having geotechnical information in a data exchange format means organizations can use available past data as well as combine it with recent data for more advanced analysis, visualization and even data mining applications.

Data exchange formats include boreholes, laboratory testing and in-situ testing together to create a practical query process. These tools have the potential to allow geotechnical engineers to evaluate correlations between data variables.

An essential part of developing a geotechnical information database is organizing the data in the same format. National regulation of a geotechnical data exchange format paves the way for the development of geotechnical databases essential for risk management during natural disasters such as landslides and floods.

Finally, due to the growing complexity of engineering projects, the increasingly shorter construction schedules, and the growth in the number of geotechnical investigations; there is great potential for increasing the efficiency of geotechnical engineering projects with computerized tools. This includes the development of dynamic geotechnical models for the design and calculation of earthworks. Together with online instrumentation measurements, it can be envisioned that in the near future, geotechnical engineers would be able to assess earthwork safety and reliability in real-time.

It is then concluded that efforts in the Brazilian Geotechnical community should be placed to regulate and standardize geotechnical information data transfer in digital format and to develop a national geotechnical investigation database. For that purpose, national quality standards and certification should be implemented. The development of Artificial Intelligence algorithms capable of “reading” and converting historic borehole reports into digital format can integrate such databases and form a live and dynamic geotechnical information network.

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