# GroundXML – AN ADDITION OF ALIGMNENT- AND SUBSOIL- SPECIFIC CROSS-SECTIONAL DATA TO THE LANDXML-SCHEME

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## Abstract

This paper describes the addition of alignment- and subsoil-specific cross-sectional-data to the LandXML scheme. Data exchange between infrastructure and geotechnical software should be made possible with this newly created *GroundXML* format. We developed the new scheme *GroundXML* as an extension of the LandXML scheme. Usually, commercial infrastructure software exports the alignment structure as LandXML file. Within these formats, the structures of the alignment are stored in different tags as axis, gradient and digital terrain model (DTM). Additional information which is necessary for geotechnical analysis has not existed in LandXML up to now. This means, that the format has not supported a semantic description of different underground layers with drilling profile, ground parameter or volumes. In order to realize a simple and automatic exchange of geometrical and semantic information between infrastructure- and geotechnical software, we have now added new elements to the *GroundXML* scheme. We use the standard LandXML format to describe the geometry of different underground layers and add new features to include the subsoil parameters from the 3D subsoil model. The description of the subsoil will be realized by the 3D subsoil model which includes the building ground properties of the corresponding layers. Afterwards a *GroundXML* instance file can be imported into the geotechnical software via a *GroundXML* interface. In a next step, the subsoil structure is analyzed and if necessary, the cross-sectional-line can be optimized. The suitability of the GroundXML formats has been tested exemplary with commercial infrastructure and geotechnical software as a part of the Bavarian research project ForBAU. The paper describes in detail the necessary steeps to create the format *GroundXML*.

**Keywords:** LandXML based format, geotechnical Data exchange, planning process, semantic subsoil description, geotechnical Database, GroundXML, geotechnical Analyse.

# 1 Introduction

Geotechnical exchange formats are gaining importance in the geotechnical software environment. These formats are used for administration, interpretation and numeric analysis of the digital subsoil data. For example the electrical transfer of boring logs or lab test data can take place with these geotechnical interchange formats [1]. The growing desire for more automated and optimized geotechnical processes demanded exchange formats that were easy to interpret and exchangeable. In the late 1980´s several geotechnical data formats were designed. The result was chaos. For this reason the Association of Geotechnical and Geoenvironmental Specialists established a Working Party, which developed the standardized format “AGS” [2]. The first edition was published in 1992. According to this format other interchange formats such as “DIGGS” (Data Interchange for Geotechnical and Geoenvironmental Specialists) [1, 3, 4] or GeoSciML (Geoscience Markup Language) [4, 5] were designed. This format generally will be used for electronic data exchange from geotechnical in-situ field and laboratory tests of subsoil data. More details about these exchange formats will be discussed later in this paper.

*GroundXML* has another view on geotechnical data transfer than the formats named above. The focus of *GroundXML* lies on the exchange of information during the terrestrial – geotechnical – infrastructural planning processes. Instead of using different interfaces for the data interchange within the planning processes a continuously data stream can realized with the help of only one format. This means that the LandXML based extension *GroundXML* stores all geometrical and semantic data from the survey, geotechnical and infrastructure planning processes. The level of the stored data depends on the progress of the planning process. The information about the terrestrial and geotechnical data will be provided from a 3D subsoil model which is linked with a geotechnical database. Subsequently the infrastructure model can be created with *GroundXML*. In the last processing steep the geometrical and geotechnical semantic data of the cross section elements are used for numerical geotechnical analysis. The big advantage of this format is that it ensures the continuous data stream for the entire planning process. The idea to develop *GroundXML* emerged during the work for the research project “ForBAU”. This Bavarian research project consists of a group of different universities and partners from the building industry. The aim is to improve the planning and building process of infrastructure and bridge construction with a virtual building site model. We use parameterized 3D models (Figure 1) of the building and the construction site as basis for a continuous planning. To integrate information about the construction processes a 4D simulation is done before starting the building work. New methods with terrestrial and airborne laser scanning are tested to capture the real building progress from the actual model. The administration of the extensive data during the planning and building process will be realized with the help of a product data management system (PDM/PLM- System) [6, 7] from the machine and aircraft industry.

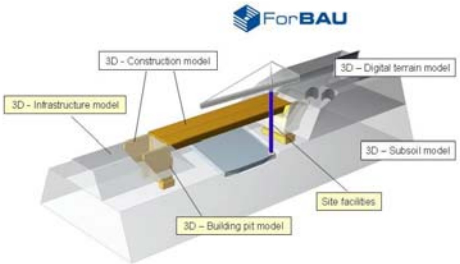

Figure 1: Virtual building site model

## 2 Motivation and data transfer in the practice

In Germany today the data exchange of geotechnical information is realized by means of text documents in either digital or print version. This means that the geotechnical reports, such as geological survey, drilling profiles, representation of ground layers or subsoil parameters for the geotechnical analysis are provided to the user as PDF documents or CAD drawings. The electronic reuse of these data is not possible and the result is that the calculation data for a geotechnical analysis has to be re-entered manually. Accordingly the process needs more time and is more expensive. An automatic import of the geotechnical data would be preferable. In other countries such as the United Kingdom [8], Singapore [9], Thailand [10] or America [11] geotechnical interchange formats are already established and can realize an electronic data exchange of subsoil investigations.
Existing geotechnical formats and terrestrial – geotechnical – infrastructural planning processes will be considered during the development of the XML based geotechnical exchange format *GroundXML*. It will be realised as an extension of the LandXML format, which is a standardized format [12, 13] for terrestrial and infrastructural tasks.

## 3 Actual geotechnical interchange formats

The potential of a standardized geotechnical interchange format was recognized by Greenwood in 1988. Since this time some exchange formats were developed and the advantages of a standard data exchange format are:

- receive data from a consultants in a standard form
- exchange information with other agencies
- exchange data between software packages and provider
- ensure a continuous data stream
- save time and resources
- produce software products that are more standardized and more compatible with other products
- utilize and analyze data from various sources in an integrated geo-environmental / geotechnical data management system [4]

A short outline about the currently existing geotechnical exchange formats will be given in the following passage.

### 3.1 AGS format

In 1991 the Association of Geotechnical and Geoenvironmental Specialists (AGS) set up a Working Group which developed the standardized geotechnical interchange format AGS. Before the first edition was published, Threadgold and Hutchinson reported the results of the AGS format on a conference in Paris in 1992 [2]. Since that time the format has been continuously extended and customized to the requirements of the geotechnical industry. The development of the AGS format (www.ags.org.uk) is based on a data dictionary of groups and fields which define the data sets, rules and the file format itself. Maximum flexibility will be ensured with the help of these groups and field structure and these define which datasets from the field- and laboratory reports are stored in the format. The transfer file itself is a text file with the data surrounded by quotes and separated by commas (Figure 2). All fields are text. An extension of the dictionary is possible if certain rules are respected [2]. The format will be principally used for the exchange of monitoring and instrumental data from field and laboratory tests which have a similar structure to the AGS format [11]. The disadvantages of this file are the large amount of limitations and the fact that it not includes any calculations or interpreted data.

<u>Same of the limitations of this format are:</u>

- it has a restrictive language
- it has rules that must be followed (e.g. a line of data can only 240 characters long)
- it lacks a logical structure
- it is not easily extensible
- it proposes to use one file for the entire project

These and more limitations confine the flexibility and usability of the interchange format in the practice, but nevertheless the AGS format has been successfully integrated in the geotechnical industry.

```
"**PROJ"
"*PROJ_ID","*PROJ_NAME","*PROJ_LOC","*PROJ_CLNT","*PROJ_ENG","*PROJ_CONT","*PROJ_DATE","*PROJ_AGS"
"<UNITS>","","","","","","dd/mm/yyyy","",""
"7845","Trumpington Sewerage","Trumpington","Trumpington District Council","Geo-Knowledge
International","Lithosphere Investigations Ltd","23/07/1999","3","FS0001"

"**HOLE"
"*HOLE_ID","*HOLE_TYPE","*HOLE_NATE","*HOLE_NATN","*HOLE_GL","*HOLE_FDEP","*HOLE_STAR","*HOLE_LOG"
"<UNITS>","","m","m","m","m","dd/mm/yyyy","",""
"TP501","TP","523196","178231","61.86","3.25","21/07/1999","ANO","FS002"
"BH502","IP+CP","523142","178183","58.72","15.45","22/07/1999","ANO","FS003"
```

Figure 2: Example for the AGS format [www.ags.org.uk/site/agsm/example.cfm]

## 3.2 DIGGS format

The DIGGS format (www.diggsml.com) enabled a standardized exchange of geotechnical and geoenvironmental data and was realized by using a XML and GML (Geography Markup Language) based language. GML is an ISO standard XML format which ensures georeferenced data. The big advantages of DIGGS are the easy transfer over the internet, the easy extensibility and the platform and software independence [3]. The DIGGS standard format has been created by combining results of existing geotechnical exchange datasets by a formed group of members from the AGS organisation, the company COSMOS and the University of Florida, Department of Civil Engineering [4]. The aim was to integrate the elements from the different institutes to one dataset in a hierarchically structured form. The DIGGS 1.0 structure consists of several top levels such as project, dictionary and equipment.

Every top level owns two sub levels which called <Subsurface Data> that stores the geotechnical data about boreholes and <Substructure Data> that include information about the deep foundation and pile test. The result is that the DIGGS format can provide the user with all data from a subsoil in-situ field test or laboratory report. However, an exchange of calculations or interpreted data is not possible.

## 3.3 GML format

The GML format is an ISO (International Organization for Standardization) standardized XML format and defined by the OGC (Open Geospatial Consortium) to describe geographical data [3]. The geological objects are described as points, line strings and polygons. In addition GML stores information about the coordinate reference system, time and unit of measure or map presentation of styling rules. This open format is used as basis by the most of the geotechnical interchange formats.

## 3.4 GeoSciML format

GeoSciML is based on the OGC (Open Geospatial Consortium) standard which allowed a software independent interchange of geoscience information [14]. The organisation CGI (Commission for the Management and Application of Geological Science) assigned a Working Group to develop GeoSciML which is an application of the GML and XMML (eXploration and Mining Markup Language) language [15]. This interchange format transfer information about the borehole, the geological structure, in-situ field and lab reports or data from the mining excavation.

## 3.5 LandXML format

The LandXML file (www.landxml.org) itself is not a geotechnical interchange format and is not based on the format GML, but it is important for the development of GroundXML. LandXML is a terrestrial and infrastructural extension of the W3C standard XML application and is used to exchange georeferenced information about the surveying and infrastructure planning processes. The structure of the dataset is defined by the LandXML scheme (Figure 3) which is an extension of the XML scheme. This format is adapted to the terrestrial and infrastructural conditions. Through the hierarchically structure and easy extensibility complex datasets can be defined and stored in this format. However semantic information of geotechnical investigations cannot transfer with this format.

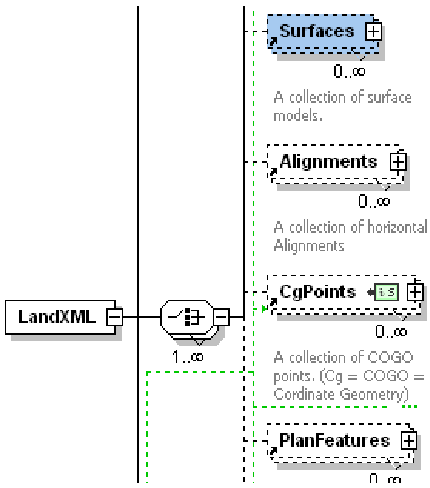


Figure 3: LandXML format

# 4 Development of the GroundXML interchange format

Paragraph 3 introduced different standardized geotechnical interchange formats. The use of these formats is the best chance to exchange geotechnical investigations and laboratory results in an uncomplicated process. However, the transfer of all geotechnical data through the whole data process is not possible with these formats. For this reason the design of a new geotechnical format has been started which should store interpreted geotechnical data and close the gap within the geotechnical data process (Figure 4). In addition it should support the terrestrial – geotechnical and infrastructural planning process. The development of this data format is based on the standardized LandXML scheme (see section 3.5) which contains all terrestrial and infrastructural elements. A network of different researchers from the Technical University Munich (Chair Computation in Engineering and Zentrum Geotechnik) and the University of Applied Sciences Regensburg (Faculty Civil Engineering, Computation in Engineering) as well as partners from the industry work on the creation of *GroundXML*.

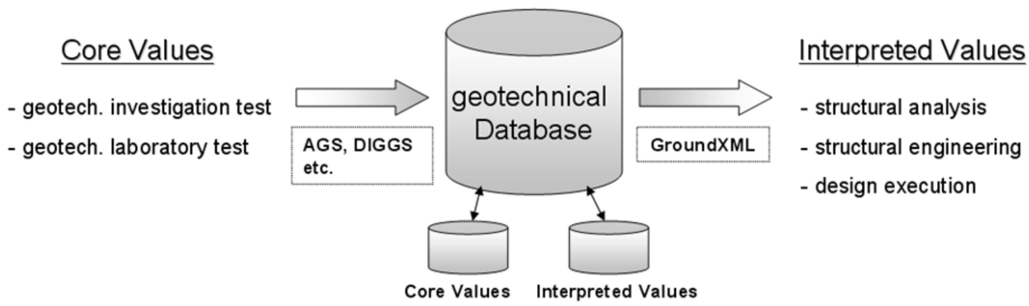


Figure 4: geotechnical Database

## 4.1 Terrestrial – Geotechnical – Infrastructural Planning Process

As mentioned in the introduction, the data exchange format *GroundXML* focuses on the exchange of information during the terrestrial – geotechnical and infrastructure planning process, especially in road and bridge construction. The success of the planning work depends strictly on the quality of the information about subsoil structure in the construction area and data from the terrestrial and infrastructural planning processes. With a special geotechnical computer-aided system like Surpac [16] and GoCAD [17] a sophisticated 3D subsoil model will be created. This 3D model provides geometrical and semantic geotechnical data. Due the restriction of the data exchange interface of traditional road design system, such as Civil3D [18], they cannot access the information contained in the subsoil model. The detailed information in the subsoil model must be reduced to adjust the existing data exchange formats which were widely supported. The key feature of the *GroundXML* is to ensure the exchange of high quality data between different engineering applications and during the whole infrastructure planning and construction phases. Further information about the planning process is depicted Figure 5.

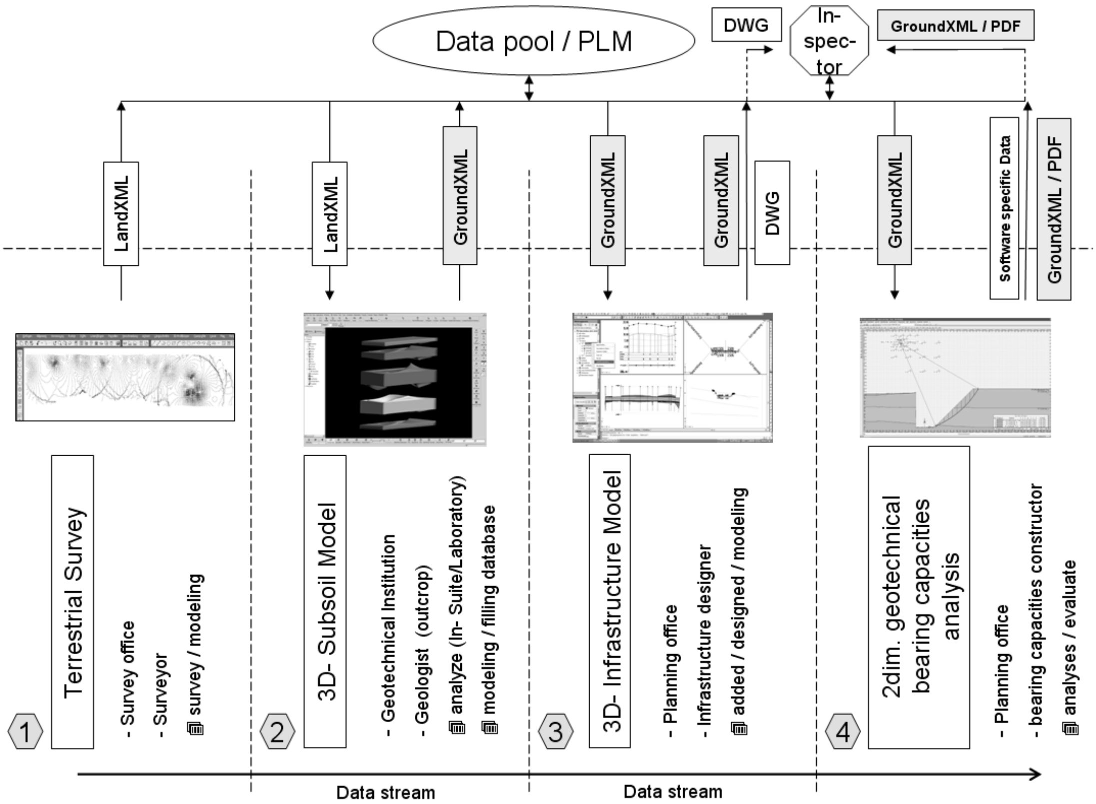


Figure 5: terrestrial – geotechnical and infrastructure planning process

## 4.2 Geotechnical database with a 3D subsoil model

Design and acquisition of subsoil information required by the geotechnical industry are stored in a subsoil database (Figure 4). The subsoil database is associated to the layers properties of the 3D subsoil model. One part of the subsoil database contains information of subsoil layers and subsoil properties in detail. This data is received by site investigation and laboratory tests on soil samples. The exchange of this information can be realized with the formats mentioned in Section 3. The simplified subsoil model is derived by the geotechnical interpreted information and supports subsoil information (e.g. properties of material) related to the earthwork. The second part of the database contains information for the construction phase and construction planning. This operation part is divided into different groups, such as *structural analysis*, *structural engineering* or *design execution*. The group *structural analysis* contains characteristic soil parameters which are representative to single layers. The demand of different semantic requirements of computation programs may render it necessary to repeat the same characteristic soil parameters in different structure of the database. With the aim to normalize the data exchange and to avoid redundancy of the different information from the 3D subsoil model such as subsoil layer or characteristic soil parameters for the structural analysis the interchange format *GroundXML* is created.

## 4.3 The realization of the GroundXML format

### 4.3.1 LandXML as basic for the further development

The standardized format LandXML builds the basis for the geotechnical interchange format *GroundXML*. LandXML is the widest established data exchange format which already supported by several terrestrial and infrastructure software. The rules of the data exchange and the meanings of the XML elements are finely structured and defined with standard XML Schema Definition Language. The LandXML format can store a lot of terrestrial and infrastructural information. The special tags are <Survey>, <Surfaces> and <Alignment> which are shown in Figures 6. The element "Survey" contains information about the surveying structure; "Surfaces" store information about the digital terrain model (e.g. soil layers) and the element "alignments" includes infrastructural data (e.g. centerline of the road). The tags can contain any number of similar sub elements which can store the different subsoil layers from the 3D infrastructure model. This property enabled the format to store the whole geometric data from the terrestrial, geotechnical and infrastructural planning process. However, the big disadvantage of this format is that it does not integrate any semantic information such as interpreted geotechnical data. For this reason the interchange format *GroundXML* is developed.

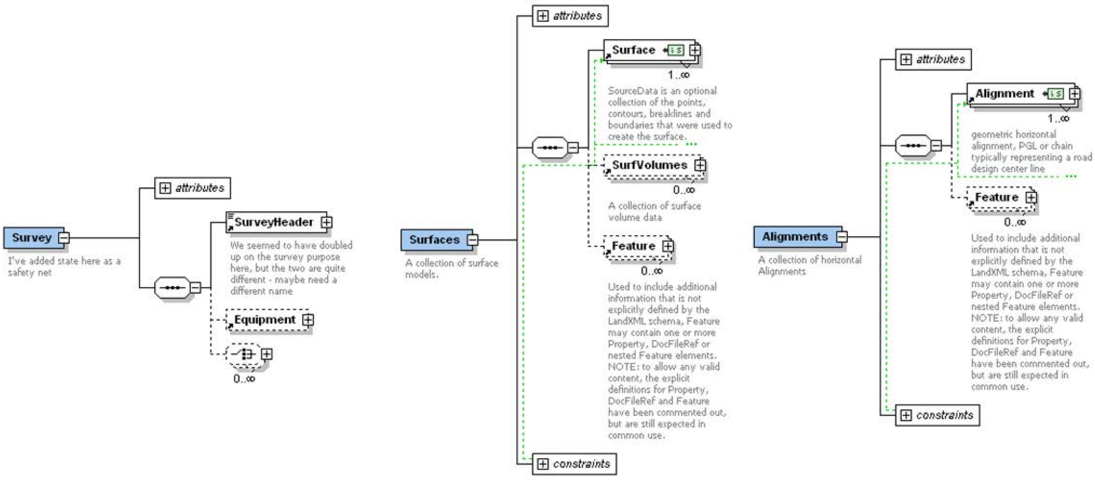


Figure 6: Tags for the terrestrial – geotechnical and infrastructural planning process

### 4.3.2 The format GroundXML

As mentioned before, the format *GroundXML* is a further development of the approved LandXML scheme. By the integration of this format an extensive development of a terrestrial and infrastructural dataset was not required and the specific planning process can be ensured. The semantic data integration of the geotechnical database is realized by additional elements in the *GroundXML* scheme. The root element [19, 20] is called "GroundXML" and includes all elements and attributes form the LandXML format and the new tags for the geotechnical structure. The new designed tag, called <Subsoil_Data> which is integrated in the hierarchically structure of the LandXML scheme. For a structured management and a reuse of the interpreted data (see section 4.2) another sub element <Subsoil_Semantic> is added. This tag is divided into three further elements (Figure 7) which store further specific different semantic information. With the help of the attribute “Soil_ID” a referencing between the semantic and geometric data is realized. This means that one geometric element like surface, subsoil layer, cross section or a quantity of points belongs to one semantic dataset.

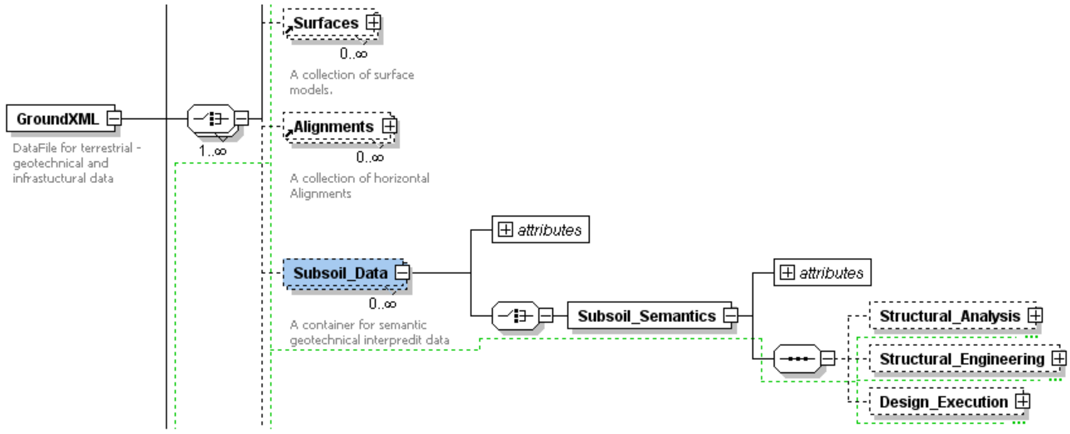


Figure 7: excerpt of the GroundXML scheme

Some advantages of the format *GroundXML* are,

- exchangeable over the internet
- easy and simply expandable
- hierarchically structured
- enable a continuous planning process (Figure 8)
- non-redundant management of geometric or semantic data
- interchange of interpreted geotechnical data (e.g. $\varphi$ = 27.5° to 30°)
- closes the gap within the geotechnical data process

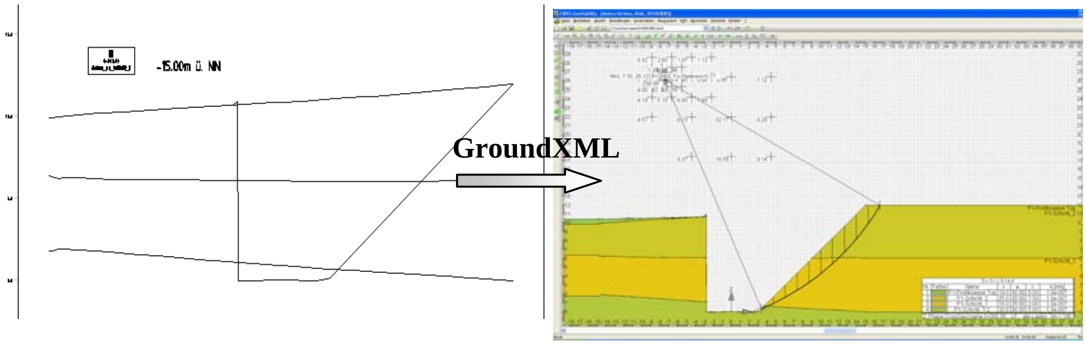


Figure 8: exchange between infrastructure and geotechnical analyse system

# 5 Summary

The interchange format *GroundXML* completes the geotechnical data process and ensures a continuous data stream in the planning and execution process. This format should not only be used as an interchange format for geotechnical datasets but also as a format to realize the terrestrial, geotechnical and infrastructural planning processes. The flexibility and modifiability of *GroundXML* is guaranteed by the XML standard. In further work results of a numerical geotechnical proofs will be integrated in the *GroundXML* scheme. This should improve the data exchange between constructors and inspectors. The interchange format *GroundXML* is hoped to become a standard in Germany's geotechnical industry.

# Acknowledgement

The presented work was carried out within the Bavarian research cluster "ForBAU-The virtual construction site" funded by the Bavarian Research Foundation [21].

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