Present Demands on Earth Structures in Transport Engineering in Europe

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Abstract One of the major challenges for modern society is to continue providing sustainable, affordable, and available transportation networks for people and goods. The challenge is twofold: (1) new structures should be built in a more resilient and a more durable and affordable manner, and (2) existing structures need to be maintained, retrofitted, or reset for a new purpose. Over recent times, different visions for improving transport engineering in these areas have been defined in Europe. Like many transport and geotechnical engineering platforms, European Large Geotechnical Engineering Platform (ELGIP) declares the readiness of the field of geotechnical engineering to contribute to the realization of these visions. The focus is on both engineering approaches and those which are helping to add a new dimension to Earth Structures in transport engineering—sustainability, availability, and affordability. This paper describes some opportunities that are currently on offer in this field. In Europe, the engineering approach is recorded in EC 7—Eurocode 7 in which the principle of limit state design was accepted, and the geotechnical categories classification is used. The second generation of EC 7 is now undergoing the final phase of preparation. The question on how to consider sustainability in Earth Structures in Transport Engineering is covered by describing geotechnical solutions for reducing energy and resource consumption. Moreover, proactive measures to guarantee transport infrastructure availability and affordability under extreme circumstances (e.g., natural and man-made hazards) are discerned. In conclusion, this paper explains why geotechnical engineering should devote appropriate attention to the use of the

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building information model (BIM) for Earth Structures in Transport Infrastructure generally.

Keywords ELGIP · Transport infrastructure · Earth structures · Sustainability · Availability · Affordability · BIM

1 Introduction

Over the most recent period, different visions for transport engineering have been defined in Europe. Politicians and investors (owners) of transport infrastructures should enable engineers to fulfill these visions. Therefore, many transportation and geotechnical engineering platforms are declaring their preparedness to contribute to the realization of these visions. ELGIP—the European Large Geotechnical Engineering Platform have prepared many supporting materials in this direction. Its focus is on both engineering approaches and other approaches which are helping to add a new dimension to Earth Structures in Transport Engineering—in terms of sustainability, availability, and affordability.

The engineering approach is now specified in Europe by Eurocode (EC) 7 Geotechnical Design where the principle of limit state design was accepted. In this paper, some possibilities in this direction will be described with respect to the second generation of EC 7 which is now in a final phase of preparation. The main focus is on risk identification and subsequent risk reduction for basic phases of geotechnical structure design and execution, as in the ground model, the geotechnical design model, the calculation model, and in structure construction (execution) with proposed quality control.

But the earth structures should not only be safe and economically efficient, but also environmentally friendly. Possibilities in this direction are now at the center of interest, as indeed is reducing energy and resource consumption as instanced for example with land and natural aggregates. For an area sensitive (or prone) to natural hazards such as landslides, flood, and rock falls, there is a tendency to increase structure robustness, to guarantee structure operation even on a limited scale and, at the same time, to limit costs for structure maintenance during life time expectancy.

The building information model (BIM) can be a very useful tool to guarantee mutual bonding of the above-mentioned aspects. In this way, it helps to stress the significance of geotechnical engineering, as well as a good cooperative relationship among the individual partners right from the start.

The presented paper will briefly describe the possibilities which geotechnical engineering is now offering and will utilize new achievements in this branch. However, only in some selected cases will a closer specificity be addressed.

2 ELGIP Activities

ELGIP was founded in 2002. Now ELGIP is a group of 14 European research organizations, leaders in geotechnical engineering, with the main aim being to promote internationally the profession, its networking, and its societal relevance. A working group on transport infra has over the last 5 years prepared different workshops, as on "Geotechnical risk management for transport infrastructure," published a vision document "Reduction of geotechnical uncertainties for infrastructure" and also distributed a position paper "The need for improved knowledge and understanding of ground properties in transport infrastructure." The organizer of the 4th ICTG 2021, after the meeting of the WG of ELGIP and TC 202 of ISSMGE supported not only the idea of closer cooperation, but also publication of the activities of the ELGIP WG at this conference.

Let us start with the main aims summarized in the position paper focused on policy makers, transport engineers, risk managers, geoscientists, and engineers, and their need to collaborate at early stages when planning, building, and maintaining transport infrastructure. Especially, cooperation in the early stages is extremely important as it is a chance to include in the design new ideas giving to the transport infrastructures (TI) such new dimensions as:

- Sustainable TI by using innovative solutions;
- Available TI by guaranteeing secure and resilient solutions;
- Affordable TI by cost optimization.

For example, innovative solutions by slope reinforcement can safeguard land, as well as demands on ground investigation, which is also important in the case of TI widening as additional land buying is a very sensitive problem. Application of large volume waste can limit the demands on natural aggregates, and the volume of embankments can be higher than the volume of cuts. In the final analysis, the position paper argues that planners and policy makers need to put money and efforts where it makes a difference—improved knowledge and understanding of ground properties.

3 Safe and Economically Efficient Earth Structures of Transport Engineering

According to [1], the European Commission agreed to sponsor the development of a set of European codes of practice for building structures and in this way to encourage free exchange between member countries going back as far as 1976. Eurocode 7 Geotechnical design was prepared in the 1980s under the umbrella of ISSMGE, but from the 1990s, the work on all Eurocodes was transferred to the European Committee for Standardization (CEN), namely that of Technical Committee 250—CEN/TC250. A subcommittee (SC 7) is responsible for Eurocode 7 (EC 7), of which a final draft was prepared in 2004. After positive voting by national standards bodies the European standard EN 1997-1, Eurocode 7: Geotechnical Design, Part 1: General rules are valid in most European countries. A similar status was obtained for EN 1997-2. Eurocode 7: Geotechnical Design Part 2: Ground investigation and testing, which came two years later. After another 5 years, the review of existing codes started, and a second generation of the ECs is now prepared and being discussed before final voting. Geotechnical engineering will be more visible as the basic code EC 0 will have a title: Basis of structural and geotechnical design. With respect to EC 7, it will have three parts.

3.1 EC 7—1 Geotechnical Design Part 1: General Rules

Generally, the design principle assumes limit states with the application of partial factors of safety and distinguishing ULS—ultimate limit state and SLS—serviceability limit states. The second generation of EC 7 utilizes either the "resistance factor approach"—RFA or the "material factor approach"—MFA. In the first case, ultimate limit states involving failure of the ground should be verified using the partial factor for ground resistance and increased factor on effects of actions; while in the second case, ultimate limit states involving failure of the ground should be verified using partial factors for material properties and actions. EC 7 is recommending these partial factors. The National Standards implementing the Eurocodes will comprise the full text of the Eurocodes followed by a National Annex (NA). A NA can only contain information on those parameters, known as nationally determined parameters, which are left open in the Eurocodes for national choice. For SLS, the recommended partial factor is equal to one.

Subsequently, for each geotechnical design situation, it shall be verified that no relevant limit state is exceeded and shall provide a level of reliability no less than that required by EC 7. However, the complexity of each geotechnical design should be determined along with the associated risk, or with an impact (consequence) of failure. Three geotechnical categories are used for any distinction in this direction.

The geotechnical categories classification influences each step of the geotechnical structure design and execution. For example, with simple structures with low risk, the design can use geotechnical parameters which are collected as the result of the experience of our predecessors and are presented in different tabular form based on soil (rock) classification. On the other hand, the structures connected with very high risk deserve the collection of undisturbed samples on which geotechnical parameters are subsequently determined. The number of such samples from each lithological layer (geotechnical unit) should be sufficient for statistical evaluation. In both cases, the designer should select the characteristic (representative) values for geotechnical parameters as a cautious estimate of the value affecting the occurrence of the limit state. Therefore, the GC classification right from the beginning is very desirable. One of the possibilities for such classification is an overview of uncertainties linked with basic steps of the geotechnical structure design and performance as in:

- Ground model—containing geological model + results of lab and field tests;
- Geotechnical design model—where for each lithological layer (geotechnical unit) or discontinuity there is selected a characteristic (representative) value, subsequently used in the next phase namely in the calculation model;
- Calculation model which includes analytical or numerical calculation models;
- Geotechnical construction—sensitivity of geo-technology to the input data.

When checking limit states of a geotechnical structure (during the phase of the calculation model) with the help of the partial factor method, the inequality given below (Eq. 1) shall be verified:

$$E_{\mathrm{d}} \leq R_{\mathrm{d}} \quad (1)$$

where
E_{d} is the design value of the effect of actions;
R_{d} is the design value of the corresponding resistance.

3.2 EC 7—2 Geotechnical Design, Part 2: Ground Investigation

EN 1997-2 provides rules for specifying the ground investigation (GI) used to gather information needed for the design and verification of geotechnical structures. The relationship between the GC and demands on sampling was already mentioned. Generally, it is valid that in the phase of ground investigation planning, the relationship between the proposed structure and methods of the ground investigation as well as required geotechnical information should be considered. Therefore, more attention is devoted to the demands of ground investigation for individual geotechnical structures than on own tests, either lab or field. The usefulness of different phases of ground investigation are described in more detail, such as desk study and site inspection, preliminary GI, GI for design, construction, and control and monitoring investigations. This latter one is able to evaluate the differences in the results during this last phase against the results obtained during the phase of the design GI. In the case of large differences, the geotechnical structure should be re-modelled for new information. The range of investigation points should guarantee that all ground volume which will be affected by geotechnical structure will have been investigated. As TIs are generally 2D structures, the verification between individual investigation points in longitudinal direction can be controlled by indirect methods, namely by geophysical ones. Therefore, our attention is focused on quicker and cheaper possibilities with a high predicative value in order to decrease uncertainties connected with the ground model. It is valid not only for ground (subsoil), but also for borrow pit. Attention is also devoted to ground mechanical response to dynamic loads and to parameters for seismic loading. The result of the ground investigation is summarized in the ground investigation report (GIR), which shall be part of the geotechnical design report (GDR).

3.3 EC 7-3 Geotechnical Design, Part 3: Geotechnical Structures

The proposal for EC 7-3 includes the following geotechnical structures: Slopes (embankments and cuts), spread foundations, piles, retaining structures, anchors, reinforced (soil) earth structures, and ground improvement. The last two were not specified in the first version and deserve a few additional notes. Still not all geotechnical structures are mentioned there, typically the most difficult structures such as tunnels or high earth and rock-fill dams. General rules are valid for them but should normally include alternative provisions and rules to those in EC 7. For example, in the case of tunnels, a special expert group was established by means of the Joint Research Center (JRC) administered by the European Commission and sponsored by CEN.

With respect to ground improvement, different techniques are classified into:

- Diffused ground improvement as, e.g., different compaction or consolidation methods, different methods of mixing and grouting, or
- Discrete ground improvement as, e.g., different vertical columns as stone, geosynthetic encased columns or jet grouting, vibrated concrete columns.

The distinction between the two basic improvement techniques has a strong impact on characteristic parameters selection. For diffused improvement, the properties of new material should be tested; while for discrete improvement in most cases, the characteristic parameters are determined for basic ground as well for discrete elements.

Ground improvement techniques are studied very intensively as they can help to reduce an expulsion of less appropriate ground from the construction process. Clayey soils with higher moisture content than optimum are a typical example, where stabilization with lime is a preferred way of ground improvement. A different amount of quick lime can lead firstly to a workability improvement (roughly up to 2%), while higher content up to 6% can lead to a strengthening improvement. New characteristic values of geotechnical parameters are selected from the tests performed on stabilized clay at least 28 days after soil stabilization. However, this process is problematic for soils containing sulfates, or where sulfates arise through oxidation of "sulfides," as in this case, the final result is sensitive to swelling due to creation of mineral ettringite.

From the viewpoint of TIs, the chapter on reinforced ground deals with fill reinforcement (mostly with geosynthetics), slope cuts reinforcement by soil nailing or, respectively, with basal reinforcement. A recommendation is given for the long-term design strength of geosynthetics reinforcement based on ultimate short-term strength. For verification of ULS by analytical methods of slices, the distribution of tensile forces in a reinforcing element is recommended with a maximum (long-term design force) at a point where the reinforcing element is cutting a potential slip surface.

4 The Sustainability Principle

It is now about 30 years since the concept of sustainable development was accepted at the highest level during the International conference "Environmental Summit" in Rio de Janeiro. Over time, this concept was gradually developed in various areas of human activity, including geotechnical engineering, e.g. [2–4] Very briefly stated, the principle is to propose geotechnical structures which are not only safe and economically competitive, but also much friendlier to the environment. However, this concept was accepted by politicians only at the highest level, while here it is a specialist duty to say how we are prepared to fulfill this concept. Usually in the field of TI, the focus is on saving land, natural aggregates, and energy (or here at least setting on lower CO_2 footprint). This can be achieved with implementation of new advances in geotechnical engineering, developing from the fact that this branch always had a very close working contact with the environment. In order to reach this new goal, full acceptance should be declared from all sides of the construction process (investors—owners, ground investigators, designers, contractors) involving them from the very earliest steps. Nevertheless, there are many different questions on how to include any savings into the total (or at least the bidding) price of the project. For example, the price of land should be included as is at the phase of design or that which can be expected during half of the structure life time expectancy. How do we express the benefit when the large volume waste can be used for the TI construction instead of depositing it at different landfills? How can we evaluate the lower CO_2 footprint? Therefore, this means that the technical solution to these problems, which will be presented below giving the simplest examples, should be accompanied by answers to these kinds of above-mentioned questions.

4.1 Savings on Land

Annual consumption of land for different activities in Europe is alarming. Many countries declared an effort to significantly safeguard land, in the first instance denoted as greenfield. The transportation network is one of the greatest land consumers. Merely to reduce land consumption or divert it on to less valuable land such as, e.g., brownfields, TI gives roughly two basic possibilities:

- During TI planning to situate it on less valuable land (brownfields) or to find such a traffic route that will need lower embankments and shallower cuts;
- To propose steeper slopes with the help of new techniques, as is, e.g., soil reinforcement.

As steeper slopes enable a saving on not only land, but also natural aggregates and energy they should be preferred, even when this solution may require better protection of slopes against surface erosion.

As buying up of land is always a very difficult task, steeper slope reinforcement (by geosynthetics for fill and soil nailing for cuts) can be a very attractive solution for any proposed existing TI widening, especially if the geomorphology allows it.

4.2 Savings on Natural Aggregates

TI uses huge amount of natural aggregates, therefore any basic effort is connected with higher utilization of different materials denoted as waste, especially where these are produced in large volume, as in:

- Construction and demolition waste—e.g., bricks, concrete, ceramics;
- Excavated soil during construction activities in cities—e.g., metro, underground garages;
- Mining waste—different waste rocks, debris;
- Industrial waste—e.g., flying ash from electric power stations, slag from metallurgy, waste (tailings) from concentrator factories.

The application of the above-mentioned large volume waste can decrease the need of their deposition on different landfills, so they can change the general principle about balance of the volume of ground excavated in cuts with volume needed for fill. However, the decision in which phase of the revaluation chain the particular residue can be used, depends on:

- Structural stability—sensitivity to structural collapse or sensitivity to swelling;
- Qualification of a leachate character and subsequent contaminant transport modeling—to approve that there is a practically negligible potential risk of environmental contamination.

Recent and current experience shows that there is a high potential for the application of large volume waste. Even a very high mining spoil heap composed from clayey clods deposited by free fall can be used for TI—[5]. There is similar validity for embankment where flying ash was deposited together with classical soil in sandwich arrangement [6]. Only one example of small volume waste can be mentioned. Small pieces of waste glass which are not appropriate for recycling in a glass factory can be transformed to foam glass. Grains of foam glass about the size of sand and gravel have a very low density of about 150–70 kg/m^3. When used as bridge abutment backfill, such material can reduce fill settlement, also earth pressure and in addition, it has very good insulation and drainage properties.

4.3 Savings on Energy

As consumption of energy used for transportation is huge, about 30–40% of all spend energy, there is now a natural trend to reduce it. In the field of transportation geotechnics, there are different possibilities. Instead of the already mentioned (lower demands on excavation and transport), they can be divided into:

- Renewable energy harvesting;
- Savings via application of new geo-technologies;
- Savings via application of geotechnical structures with lower demands on energy or with a lower CO_2 footprint.

ELGIP common European research project COST called GABI was focused on thermo-active structures—energy piles, diaphragm walls, and tunnel lining. Pipes installed in these structures can, with the help of reversible heat pumps, extract heat from surrounding ground in wintertime and deposit there heat in summertime. In transport engineering, this system is applied for tunnels, foundations of bridge piers as well as for bridge abutment. Harvested energy can be used for the transport infrastructure surface, in order to limit extremely low and extremely high temperature there. Toward a similar purpose of utilization, the energy can be harvested also from a low depth. Earth areal heat exchanger can be placed on the contact of the embankment with the ground. Numerical models of heat transfer are exploited to define the total amount of energy which can be extracted for specific ground conditions.

Soil compaction is a basic technology for embankment construction. Selection of the optimal type of compaction technique, as well as thickness of the compacted layer and frequency and amplitude for vibratory technique is the first possibility to limit energy consumption during this process. A significant step forward was achieved with rollers denoted as with continuous compaction control (CCC) or as intelligent compaction. Last year, a special symposium was dedicated to the 40 years anniversary of this technology [7]. Besides the main output—to be informed directly about the compaction result—this technology can decrease energy demands via optimization of roller passes and via savings on classical control in a lab. Other possibilities are tested for rollers with non-standard shape of drum or with non-circular compacting masses.

In building engineering, the term “smart buildings” is now very fashionable, where the term “smart” is mostly connected with structures which need less energy with a lower CO_2 footprint. Politicians have declared the intention to stop or limit atmospheric concentration of CO_2, and therefore, geotechnical engineers should also try to follow in this direction. For example in [8], there is already approval that classical concrete retaining wall needs more energy with a higher CO_2 footprint than a retaining wall from made from reinforced soil. However, to be able to declare more examples, we need to be more familiar with this energy as a CO_2 calculation, as up to now, it is out with our field of competence.

5 The Availability and Affordability Principles

Demands on the mobility of both people and goods have been increasing steadily over time, and safe access to certain places at certain times is expected to be guaranteed not only under usual conditions, but also under circumstances resulting from natural or man-made hazards including accidents.

Three proactive measures mentioned in this chapter include a better forecasting of unusual and emergency events, increasing structural resistance and finally, emergency action planning.

5.1 Resilience of Infrastructure in the Context of Climate Change

At present, it is obvious that average temperatures have been increasing and registered in most European countries over at least the last 50 years. Therefore from the viewpoint of available and affordable infrastructures, it is important both to adapt the existing infrastructure to any climate change and to consider climate change when designing new constructions. The effects of climate change on the subsurface and on the infrastructure will vary between different countries in Europe; but in all countries, it is important to take this matter into account. Extreme events seem to become yet more extreme and more frequent. Increased and more intense precipitation, sea level rise, increased water flow, storm surge, more surface water, increased periods of freezing and thawing (zero crossings), and more drought in summer can be included among the climate change effects.

Extreme weather may have a significant impact on any infrastructure. Sea level rise and water-related effects may lead to flooding and erosion that also might influence the bearing capacity and the stability of slopes and embankments. The probability of natural hazards like landslides and rock fall will also increase. More thawing and snow melt can increase water content in base or sub base layers in road embankments followed by cracking and degradation of pavements. Heat waves and droughts may induce shrinkage of the soil leading to differential settlements.

Adaptation of existing infrastructure should be undertaken to reduce future damage. The measures can be different depending on the problems. Uncertainty in climate predictions must be considered, and different climate scenarios should be used for assessing the resilience of existing infrastructure. Planned infrastructure should be more robust and designed to be more resilient to changes in conditions. Hazard mapping, risk analysis, and risk management should be performed to help in considering the climate change effect on any infrastructure. Monitoring could be used on existing infrastructure as an early warning system. It is also important to develop the methods available for decision makers.

Many research projects have been studying the different phenomena and the effect they have on infrastructures as in [9] and [10]. There are also a many ongoing research projects in Europe with the purpose of getting a deeper understanding of the effect of climate change and to find solutions for existing infrastructure and design methods for new infrastructure. One such example is the European project INTACT which deals with the impact of extreme weather on critical infrastructure.

As the expected temperature increase has the highest impact on floods, landslides or rock falls, the interaction of these events with TI is now at the very center of our interest.

5.2 Landslides

According to [11], landslides create roughly 17% of all negative impacts caused by natural hazards. As a result, an ELGIP workshop arranged in Paris 2019 was also devoted to this problem. The problem of slope instability is especially sensitive for areas prone to landslides, as is also these areas—with respect to their range—that should be used for TI. Typical problems are connected with:

- Landslides in quick clays;
- Landslides along a contact of quaternary layer with elder fine sediments, as, e.g., claystone;
- Landslides with over-consolidated fissured clays or weak rocks.

The first case is typical only for a limited number of countries and is the subject of interest on International Workshops on Landslides in Sensitive Clays (IWLSC), the last one arranged in Trondheim 2017. Two other cases are more general. An increase of the ground water table in the quaternary layer can decrease slope stability to reach a limit state of instability and can be a reason for shallow planar landslides, [12]. If during such a situation, man-made impacts are also realized, as in cuttings in the lower part of the slope or deposition in the upper part of the slope, the slope instability is more realistic [13, 14] describes large landslides affecting the highway A7 in Granada with a mobilized volume greater than 1.5 million cubic meters. Dolomitic karstified and fractured marbles are overlaying phyllites which are in their upper part highly weathered. Cuts for motorway in phyllites that initiated horizontal deformation with progressive slip development passing through this material for which a residual angle of friction 13° was measured with a ring shear apparatus. In the upper part, the slip surface went through cracks in the marble. Remediation measures were proposed, combining such different possibilities as pore water pressure reduction (by vertical drains), excavation of material in the upper part, and finally, the construction of a retaining wall from diaphragm panels in the lower part.

5.3 Floods

Nearly one third of all natural hazard damage is attributed to floods. One of the problems relates to the higher utilization of flood prone areas. Given expected climatic changes, an increase in attention is fully justified. Among the main problems, now investigated are:

- Foundation of bridges;
- TI such as road and railways embankment in direct contact with floods;
- Flood protection measures such as dikes, small dams the surface of which is used for TI.

During floods access to bridges is usually limited or indeed the bridge is closed. Reopening after a flood, wave decrease is associated with a structure check, when attention is not only focused on the upper structure, but preferably also on pier foundation. The higher level and speed of flowing water causes scouring of ground along bridge pier which can lead to failure. Therefore, the depth of scouring for an expected maximum water level has to be calculated and compared to the foundation depth. As the foundation depth is usually low for historical bridges, in that case, the problem is extremely sensitive. Charles bridge in Prague, founded in the fourteenth century, is one such example. Reference [15] described the interaction of bridges with floods for the Po River in Italy.

For direct contact of embankments of TI with floods, two basic examples have a different approach. When the TI embankment is close to, and parallel with, water course surface erosion of slopes, then it creates a very sensitive place. As these most sensitive places can be detected in advance, the protection measures should be realized as soon as possible. When the TI is intersecting the water course, there is a potential problem with culvert blocking. The water level is going up, and seepage through the embankment can start. Practical examples show that partly saturated less permeable material is most dangerous, as enclosed air bubbles can cause upheaval and slope instability [16].

The last case of interaction is typical for dikes and small dams the surface of which is used for TI. The character of any failure tends to be caused by internal or surface erosion. For historical small dams, the sensitive place with respect to the internal erosion is along the old bottom outlet, often a wooden one. The connection with surrounding ground is often affected by the vibration of heavy trucks. Surface erosion is playing a most important role when the crest is overflowing. Asphalt pavement can significantly increase resistance against surface erosion. Similarly, some protection measures on the downstream slope are recommended, e.g., geosynthetics matrasses.

A last note is devoted to the potential flooding of a metro system as occurred in Prague during heavy floods in 2002.

5.4 Rock Falls

Due to heavy traffic increases as well as the expected climatic changes, the problem of interaction of TI with rock falls has been getting greater priority in recent times. Protection measures applied on the slope are developed as well as protection barriers at the slope toe. Numerical modeling of individual rock block falls can help to design these barriers for expected impact force. However, the same care is devoted to emergency action planning. In the case of direct access to the individual blocks which can fall down, the installed sensors control their movements and when crossing limits defined in advance, the control point is alarmed or the TI closed [17]. When there is no such access, the slope is observed geodetically or by geophysical methods with respect to observed points or blocks movement. Reference [18] describes the utilization of ground-based radar interferometry for such purposes.

6 The BIM Model

For BIM—the building information model there exist different definitions. One of them describes BIM as an information database which can encompass all data starting from the design, through the construction phase, the management facility, on to maintenance and right up to the demolition of structures. A 3D digital model of structure is the basis of the BIM model, enriched by other information such as time, financial expenses, structure management, etc.—by which we can refer further to 4D, 5D, and then generally concerning nD models.

The implementation of the BIM model is a little bit slower for civil engineering structures than for building engineering; but in some countries, this model should be used for significant structures financed from the governmental budget. For the Czech Republic, the starting year is 2022.

Geotechnical engineering is playing an irreplaceable role in the whole process as all structures are founded on ground, and the interaction of an upper structure with ground is secured by foundation structures. Also earth structures as well as underground structures are in interaction with ground, and therefore, partial models entrusted to geotechnical engineers will be covered by models similar to those mentioned in EC 7—the ground model, the geotechnical design model, the calculation model, and finally, a model of the fully realized geotechnical structure placed into the last ground model.

The exploration of such a model will have different levels:

- Information such that the range of the ground investigation corresponds to the demands of structure design;
- Information on whether the structure was constructed in accordance with the previous demands;
- Information about an individual element of the structure—e.g., for each day, the range of compacted layers can be controlled together with results of compaction

control, preferably if continuous compaction control (CCC) was used and having also GPS, and this, together with information from which borrow pit the soil for this layer, was excavated and what properties it had;
- Information for future purposes should a designed geotechnical structure have some problems (e.g., during any interaction with natural hazards or man-made accidents) or in the case where a new proposed structure would be in interaction with an existing one.

The BIM model creates a new level for civil engineering, and our specialist branch can play a very important role here. Therefore, we have to pay close attention to this new approach from the start or as early as possible.

7 Conclusion

This paper shows that, according to ELGIP (the European Large Geotechnical Engineering Platform), geotechnical engineering offers many opportunities for contributing to the realization of visions on new and existing transport infrastructure. These opportunities occur in both engineering approaches (EC 7) and approaches which are helping to add new dimension to Earth Structures in Transport Engineering—sustainability, availability, and affordability. In conclusion, to seize all the opportunities (including those described in this paper), geotechnical engineering should devote proper attention to the use of BIM for Earth Structures in Transport Infrastructures.

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