

2nd Generation of Eurocode 7 – From ground investigation to design implementation in execution, with the Ground Model as one tool

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ABSTRACT: An important consideration in geotechnical design, emphasised in the 2nd generation of EN1997, is the need to ensure successful implementation in execution, and that this is addressed as an integral part of the design process and not as a subsequent action. This paper addresses the principle that data in a project should be carried through the whole journey from initial concept and desk studies to implementation on site, using the Ground Model as an example of one of the tools available to designers to achieve this. The Ground Model is a live document that is maintained throughout the life of the project. It ties together the initial information gathered as the project is instigated and then modified and added to as information becomes available during the project. This includes the execution phases, during which valuable data can be gathered, allowing for the validation of design assumptions.

KEYWORDS: Eurocode, Ground Model, design implementation.

1 INTRODUCTION

The construction process needs to be treated as one workflow, from the concept design right through the execution of works on site and the eventual handover to the Client. The design codes and execution standards are separate documents; however, often each is implemented by different organisations, which can lead to dislocation in approach. To try and help reduce this effect the second generation of EN1997 has introduced a specific clause to address implementation of design in execution. This paper presents how this can be approached and addresses the underlying principle behind it through the example of the Ground Model.

The Ground Model is defined in the second generation of Eurocode as a ‘site-specific outline of the disposition and character of the ground and groundwater based on results from ground investigations and other available data’. The Ground Model is to be developed into the Geotechnical Design Model (GDM) during the detailed design phase.

During execution, the Ground Model and GDM form the basis for enhanced information and communication of ground conditions:

- The encountered ground conditions should be checked for compliance with the Ground Model and GDM in line with appropriate provisions included in the Inspection Plan.
- For the preparation of the execution of work on site, such as excavation, temporary structures, setting up cranes and heavier vehicles.
- Back calculations of monitored behaviour to verify the assumed performance of the structure.

2 GROUND MODEL

The Ground Model of the zone of influence (ZOI) for a project is defined in the Eurocode as a ‘site-specific outline of the disposition and character of the ground and groundwater based on results from ground investigations and other available data’.

There are two distinct models in the 2nd generation Eurocode 7: the Ground Model (in EN 1997-2:2024), which includes geology and presentation and evaluation of test results, and the geotechnical design model (in EN 1997-1:2024), which covers the design of the structure, and so includes the selection of the geotechnical design parameters.

Figure 1 illustrates how the GDM is an extension or development of the Ground Model, but is a separate model in

its own right. The GDM includes representative and design values of the relevant geotechnical properties for the structures under consideration for any specific design situation. This distinction between the Ground Model and GDM is essential because both models are subject to ongoing review and update as additional information becomes available during execution.

The Ground Model is a compilation of data derived from various sources, including maps, plans, sections, and reports, which capture objective information regarding soil and rock types, as well as groundwater conditions, across the zone of influence. The Ground Model should encompass the site and its surrounding area to provide the geotechnical and geological context, as well as information on the surrounding conditions that may impact the earthworks. The Ground Investigation Report, referred to in the Ground Model, should be considered the primary source of factual data for the site's ground information.

The ground Model is intended to utilise the distribution of geotechnical units within the ZOI, along with an interpolation of factual data and, where appropriate, derived values, to produce the most likely indication of ground and groundwater conditions for this phase of a project.

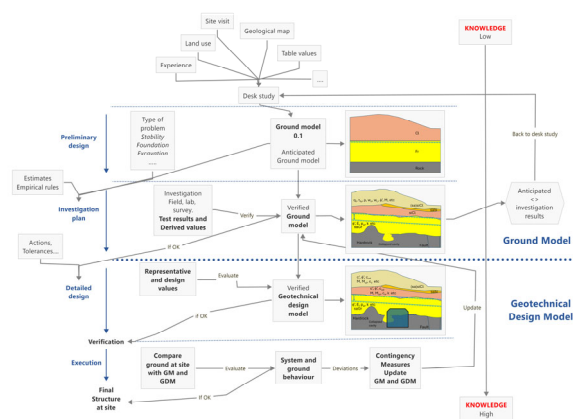


Figure 1. Relationship of Ground Model to Geotechnical Design Model and execution. Source: Franzén et al. (2025)

The purpose of the ground investigation program is to mitigate project-specific critical ground risks related to uncertainties in the Ground Model. Therefore, investigations

should not commence until the development of the Ground Model has begun. Ground investigations are also used to enhance the Ground Model to achieve a level of detail that covers issues in the execution phase.

The Ground Model should be developed in conjunction with the compilation of the Ground Investigation Report (GIR). The horizontal blue dotted line in Figure 1 shows the delineation between the Ground Model and the GDM. All data and information related to the ground and groundwater conditions for the Ground Model area should be captured and presented within the GIR.

As part of its development, the Ground Model will necessarily contain interpretations of the geometry of geotechnical units (ground conditions) and groundwater conditions. However, the transition from the Ground Model, which essentially comprises a representation of factual data and is presented alongside the GIR, to the GDM, which is linked to the Geotechnical Design Report (GDR), requires understanding and recognition. The GDM and GDR both comprise interpretative design information that utilises and builds upon the data contained in the Ground Model and GIR.

3 IMPLEMENTATION OF DESIGN IN EXECUTION

3.1 General

At its simplest level, the success of a construction project depends on how effectively the intent of the design, reflecting the needs of the Client, can be turned from theory into practice. The flow of information is not one way however, and there should be feedback to the design team to ensure that what is being encountered on site matches with the assumptions made.

The importance of ensuring the right information is passed on through the design process is identified within the design codes. There is a specific clause within EN 1997-1:2024 (cl10 Implementation of design) that directly addresses this topic. There is also a reference in EN 1990:2023 Annex B, B.7, Inspection during Execution, and B.8 Technical Management measures that also point the designer towards their obligations in this regard.

Key to this is effective and appropriate communication between all parties and attention to the level of information passed along. The method of communication needs to be appropriate to the scale of the project and complexity of the geotechnical works without introducing unnecessary levels of bureaucracy. It also needs to address the increasing use of digital communication methods, but also take into account the level of digital maturity of the entire supply chain and not just the top tier of Client and Main Contractor/Principal Designer.

The process needs to combine the different standpoints and inputs that each party has in the process:

- The Contractor is the one carrying out the execution of the works, so they need to be able to judge if they are still within the design assumptions or outside of these, based on supplied information.
- Only the Designer can assess what is significant to the design and whether a change in conditions is critical or within design assumptions.
- The Contractor needs to be supplied with sufficient relevant information to be able to proceed but also know what are hold points and what requires referral back to the Designer.

3.2 Implementing the Ground Model

At the start of the project the Designer will need to review what information is passed to them by the Client and make an assessment of what additional work will be needed to create the Ground Model they need to carry out the design. As this information is received and the design progresses to the next stage, it should also consider if there is information that needs to be gathered at this stage which will influence the construction of the geotechnical works. This may require engagement with a specialist contractor in order to get the necessary input into the information they would require.

At this stage the most basic Ground Model has been created from the Client information and then updated by the Designer with the information they have collected (from desk studies or site work). The flow of information is progressing in the same direction as the design and construction process as at this stage the Designer would not be passing back a Ground Model to the Client.

In the next phase the Designer is passing the Ground Model onto the Contractor in order to allow them to assess what methodology to adopt and what measures will be required to deal with the expected ground conditions. The design output will contain critical aspects that need to be passed along to the Contractor to ensure that the design is complied with. These will be items such as required founding criteria, expected strata to be encountered and likely rock strengths. There is an opportunity at this point for the Contractor to confirm expectations from the Designer and also highlight any shortfalls in the information provided. The information flow relating to the Ground Model is still mostly heading in the same direction as the overall project as there will be limited updates from the Contractor.

The Contractor will have their own requirements for information from the Ground Model. They need information relating to the construction process rather than design parameters. It will focus on the physical properties of the strata that could influence issues such as bore or panel stability, rate of excavation, methodology and wear on tools. If this information is not already highlighted in the Ground Model, at this stage modifications or additions will be needed. This is where an early engagement between the design and construction teams will lead to efficiencies later in the project.

As the Contractor proceeds to carry out the execution of the works more information will become available to confirm or challenge the Ground Model assumptions. This is the stage of the project where the flow of information starts to return towards the Designer, and they need to be prepared to review and analyse this as required. As a result, the lines of communication between the parties are important to ensure that the data from the site can be fed back to a different team efficiently. The Designer can then update the Ground Model to reflect the emerging site data and verify the effect it has on the design solution. Even if there is no impact on the solution, the Ground Model will need to be updated to keep the GDR up to date. This is a continuous process through the execution phase. At the end of the project, the updated Ground Model forms part of the information handed over to the Client.

4 IMPLEMENTATION PLANS

Plans are a requirement of the design code, but it is left to the designer to decide on the form they take. EN 1997-3 clause 10 specifically identifies plans for Inspection, Supervision, Monitoring and Maintenance to be created by the Designer, see Figure 2. These plans are intended to become a part of the GDR rather than being regarded as purely execution documents. This links the plans back into the GDM. The complexity and

technique involved in the project will dictate the level of detail required in the plans.

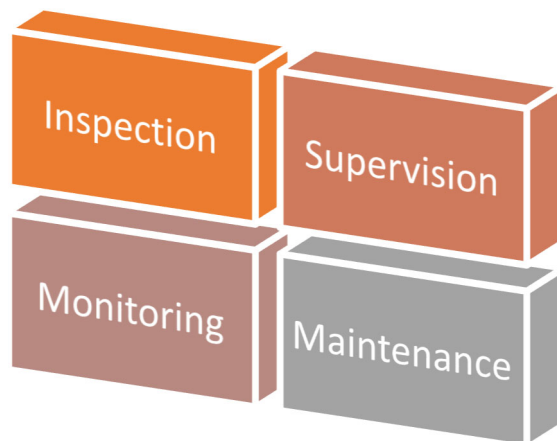


Figure 2. Illustration of plans – required by the design code.

The Designer should start with a review of the relevant execution standards as they will already cover some of the required aspects and should be referred to rather than duplicate information covered in them. There are other standards relating to field and laboratory test, plus ones covering monitoring in addition to national and project relevant specifications. The aim of the design plans required by the code is to highlight the elements from all these separate documents that are critical to the design and ensure that they are incorporated properly into the execution and quality process. It is normal for there to be several different standards that are all relevant to the geotechnical structure being designed and built.

The monitoring, supervision and inspection plans will all result in information being recorded that could relate to the Ground Model. Accordingly, the plans need to be clear on what information is to be relayed back to the design team who will require a plan of their own on how to use this information to update the Ground Model. The information that is collated through the plans also needs to be aligned with the acceptance criteria and limits that have been set for the project. This will ensure that the required information is collected and distributed to the right people to assess the implications, if any.

5 ACCEPTANCE CRITERIA AND CONTINGENCY MEASURES

5.1 Acceptance Criteria

Acceptance criteria are a framework that allows the performance of the structure during execution to be correlated back to the design. The criteria used can typically be divided into three general categories:

- Allowable execution tolerances – allowable deviations in geometry
- Performance indicators – comparison of observed behaviour with design predictions
- Serviceability limit state criteria - limits on observable quantities to characterize the behaviour in service conditions

Execution tolerances need to be defined within the design, but it will normally be sufficient to refer to the execution standards. However, depending on the structure, ground conditions and adjacent structures, these may need to be tightened or relaxed to suit the project requirements. The Ground Model will identify particular conditions such as very

soft strata that may require additional measures or allowances to be made.

Performance indicators and serviceability limit state criteria will have to be defined by the designer on a case-by-case basis as they are linked to the structure and the surrounding assets. There will always be an element of engineering judgment required to set these values within the context of the project. The criteria will be set not just for the new structure but also for the assets within the zone of influence. The Ground Model plays a critical role here in assessing what third party assets might need to be considered in relation to the behaviour of the new structure.

The limits set on performance indicators should be clearly distinguished from the limits set to meet the serviceability conditions. The performance limits are in place to take into account the level of confidence in the design predictions, and are giving a direct correlation to the design assumptions. The serviceability limits are directed at ensuring that the performance is within the proscribed limits. However, both sets of these limits need to be set within the design and aligned to ensure the most efficient use of the monitoring process. Serviceability criteria need to be further broken down depending on whether they relate to architectural damage that effects the appearance, functional damage that effects the use of the structure or structural damage that effects the safety of the structure.

In the absence of any other guidance in relation to third party assets, there is guidance on EN 1990 Annex A.1.8 on serviceability limits for buildings that cover vertical and horizontal deformations, vibrations and limits on foundation movements. These relate primarily to aesthetic and serviceability requirements and so structural checks will still need to be considered if these are adopted.

The limits need to be set on parameters that can be measured, such as displacements, deformations or strains. It is important that the criteria chosen are ones that will allow the identification of behaviour that deviates from the design predictions as soon as possible. The results of the measurements of these indicators can then be taken by the Designer and used to back analyse the design and confirm the assumptions. If necessary the Ground Model will be updated at this point to reflect the changes revealed by the performance of the structure as executed.

Limits need to be set at values that are appropriate to both the behaviour of the structure and the resulting impact on adjacent assets. It is possible that it is the tolerance of the adjacent structures that set the limits rather than serviceability limits of the geotechnical structure under construction.

Setting of the criteria needs to take into account:

- The impact of any negative behaviour and how and at what cost it could be reversed.
- The time required to implement any contingency measures or corrective actions
- What level of margin of safety is needed to implement any alternative design solutions

5.1.1 Setting limits

A common method of setting limits for acceptance criteria is through the adoption of a “traffic light” system, where a green, amber and red trigger level are set. The Green threshold is set so anything up to that value is within the expected behaviour. The Amber threshold is then set to be at a level where the measured value is at or approaching the predicted behaviour. The Red limit is taken as the point where acceptable values have been breached, and immediate action is required. These limits may be set based on predictions of behaviour or on

serviceability limits depending on the structure or asset concerned.

The exact value of the limit for each banding will depend on the project and requires engineering assessment of the risks and potential for damage if breached. However, a suggested starting point could be:

- Amber limit: 50-60% of serviceability limit or 110% of predicted value
- Red limit: 90% of serviceability limit or 130% of predicted value

These need to take into account the level of confidence in the prediction of limit values, and allowing for some acceptable variation in performance. The choice of approach adopted will depend on the structure and the behaviour being monitored. These limits need to allow for the presence of adjacent assets and it may be their condition that sets the limits for the new structure.

As the structure is monitored during execution and results are fed back, there may be revisions to the Ground Model that lead to the trigger levels being revised up or down.

5.2 Contingency measures

If limits are set, it then leads to the need for contingency measures also to be set for the situation where these limits are breached. These contingency measures need to be identified at the design stage so that they can be explained to the project team in advance and acted on as required.

As long as the measured values lie within the Green Trigger level, there should be no need for action, other than monitoring the results to match them with predictions and see if the Ground Model requires modification. This will ensure that as values approach the Amber limit, the team is aware and ready to act if required. As the Amber trigger level is reached it would normally require a review of the measurements to ensure that they are true and accurate. The next step will depend on the stage of the project. If execution is almost complete, it may be sufficient to monitor for the last stages of the project, but no additional review of the design. Otherwise, an inspection of the assets impacted should be carried out for signs of distress or damage and any relevant third parties informed. It may be necessary to perform a full analysis of the results to understand the trends being seen and make an assessment of the implications if the movements continue in the same way.

A breach of the Red trigger levels would normally result in a stop in the works until assessments have been completed. The level cannot be reached without first passing the Amber value, and so analyses of the data should have already been ongoing and the trends being monitored. Adjacent assets should be inspected in collaboration with the owners, and if necessary, their use should be limited if there are concerns over structural stability.

The Ground Model will have been reviewed and potentially updated to reflect the observed behaviour as execution is progressing. As the end of the monitoring process is completed and the actual behaviour analysed for alignment with the design, a final version can be developed that then feeds back to the Client as part of the GDR.

6 CONCLUSIONS

A project is not fulfilled until the entire process, from idea to handover, is completed. To assist in verifying safety, serviceability, robustness, durability, and sustainability, the Ground Model serves as a tool, together with the supervision plan, monitoring plan, and inspection plan. The creation of the required plans and the integration of how to implement changes

into the Ground Model needs to be addressed by the Designer at an early stage in the design process.

Strong communication between the Designer and the geotechnical Contractor is required to ensure a smooth and successful implementation of the design. Early engagement between both parties is an efficient method of creating collaboration within a project.

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