

# Geotechnical engineering and eurocode 7 construction essay



**ASSIGN  
BUSTER**

Driscoll and Simpson (2001) state: ' Geotechnical engineering has long stood out from the other professional disciplines within civil and structural engineering- not least for their approach to design'. Geotechnical design is an engineering design relating all elements involving the ground, including foundations of projects. EN 1997 Eurocode 7 is the British Standard for this design, Geotechnical Design, which replaced the old standard DD ENV 1997-1, DD ENV 1997-2, DD ENV 1997-3 and partially the BS 5930: 1999 and BS 1377-9 (Eurocode 7-part1, 2004). It is divided into two parts; BS EN 1997: 1 2004 Part 1 General Rules and BS EN 1997: 2 2007 Part 2 Ground investigation and testing (Eurocode 7-part1, 2004). The first part was published on 22 December 2004 and the second on 2007 under the authority of the standards Policy and Strategy Committee and it was corrected in February 2009. From April 2010 it is mandatory for the all the public works. Eurocode 7 is very different from the old codes for geotechnical design as it is a comprehensive limit state. It contains some fundamental design requirements that must be satisfied by all the structures. It also uses characteristic values and partial factors with three design approaches. It can be defined as a useful tool which provides guidance for geotechnical design offering the necessary requirements for stability, strength, durability, serviceability and safety for the structures (Orr, 2002). A system of three geotechnical categories was introduced in this code which helps to classify risks in design. This chapter focuses on these changes from Eurocode 7 to Geotechnical Design.

## **4. 1. History of Eurocode 7**

In 1976 the European Commission decided to support the development of European codes for buildings structures (Beal, 2010). In 1980 the European Commission requested the International Society of Foundation Engineering and Soil Mechanics to review the existing codes about geotechnical design and draft a code called Eurocode 7 (Driscoll and Simpson, 2001). The Society, after many international meetings and consultations, presented the first draft model of this code in 1987. After three years work on the code, in 1990, the code was transferred to European Committee for Standardization (CEN) for more development, issue and maintenance. In 1994 the part 1 of the Eurocode was published as prestandard ENV (EuroNorm Vornorm) and after one year was published by British Standards Institution (BSI). The code was further developed into a EuroNorm (EN) standard in 1997. In 1998, a commentary was published in UK to help engineers to understand better the use of Eurocode and give some examples of its application. In 1999 more explanations about Eurocode were published (Driscoll, 1997). On 22 December 2004 the European standard EN 1997-1 Eurocode 7: Geotechnical Design, Part 1: General Rules and in 2007 the European standard EN 1997-2 Eurocode 7: Geotechnical Design, Part 2: General Rules were published under the authority of the standards Policy and Strategy Committee. The Eurocode was written in three languages; the official EU languages English, German and French. In 2006 the national Annex (NA) was written. Eurocode was corrected in February 2009. From April 2010 its use is mandatory for the all the public works (Eurocode 7-part1, 2004).

## **4. 2. Scope of Eurocode 7**

Eurocode 7 is developed for the following reasons:

To establish the requirements and principles for serviceability and safety, explain the basis of design and also of verification and give guidelines for structural reliability when used in conjunction with EN 1990.

To be applied in geotechnical features of the design of civil engineering works and buildings

To provide the necessary requirements for stability, strength, durability, safety and serviceability for the structures.

To give the appropriate rules for the calculation of actions imposed by the ground like earth pressures.

To treat matters of workmanship and execution (Eurocode 7-part1, 2004)

Eurocode 7 is used in conjunction with the National Annex, EN 1997. This standard provides alternative values and procedures which gives notes where national choices are made.

## **4. 3. Structure of Eurocode 7**

Eurocode 7 is divided into two parts:

BS EN 1997- 1: 2004 Eurocode 7: Geotechnical Design- Part 1: General Rules

BS EN 1997- 2: 2007 Eurocode 7: Geotechnical Design- Part 2: Ground investigation and testing

EN 1997-1 provides design guidance and actions for the geotechnical design of civil engineering works and buildings (Eurocode 7-part1, 2004). The important points of this part are that it gives emphasis on the serviceability necessity for geotechnical design and on the importance of geotechnical investigations (Driscoll, 1997). It gives the definitions of ground parameters, information about characteristic and design values and some assumptions about the execution procedures. It is a useful tool for designers, clients, public authorities and contractors (Eurocode 7-part1, 2004). It gives little information or assistance in designer analysis, these are obtained in other texts for more information. Driscoll (1997) points out that the code is also used in conjunction with other CEN documents and Eurocodes.

In general EN 1997-1 covers the following topics:

Basis of geotechnical design

Geotechnical data

Supervision of construction, monitoring and maintenance

Fill, dewatering, ground improvement and reinforcement

Spread foundations

Pile foundations

Anchorage

Retaining structures

EN 1997- 2 is used in conjunction with EN 1997-1. It provides guidance for planning and reporting of ground investigations, for interpretation and evaluation of test results, gives requirements for field and laboratory tests, and derives values of geotechnical coefficients and parameters. It is used by designers, clients, field testing laboratories, public authorities and geotechnical laboratories. Moreover, examples of field and laboratory test results are given. It does not provide guidance for environmental ground investigations (Eurocode 7-part2, 2007).

EN 1997- 2 covers the followings topics:

Planning of ground investigation

Soil and rock sampling and groundwater measurements

Field tests in soil and rock

Laboratory tests on soil and rock

#### **4. 4. Geotechnical Design based on Eurocode 7**

The implementation of Eurocode 7 changes the geotechnical design process from the old standards. According to Kavvada (2007) these changes were required for the following reasons:

Eurocode 7 offers a uniform design method of structural and geotechnical works.

It offers a uniform design method of works in European Union.

It provides professional engineer's ' cover' (designed by EC 7-1)

<https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>

It provides more rational management of safety issues

The changes in the Eurocode 7 to Geotechnical design are as follows.

#### **4. 4. 1. Design Requirements**

Eurocode 7 contains fundamental requirements that must be satisfied by all structures in the geotechnical design. For these requirements there are no alternatives unless justified in specific situations. They contribute to the structural safety, serviceability and durability. Some of these requirements as referred in Eurocode 7-part (2004) follow:

It shall be checked that no relevant limit state (as defined in EN 1990) is exceeded in each geotechnical design.

The following factors should be taken into account when defining the design situations and limit states:

Site conditions

Size and nature of structures: simple, light, on good firm ground structures or large, sensitive structures on soft ground or deep excavations near to old buildings. It should be used simplified design procedures for light and simple geotechnical structures and calculations with more extensive investigations for more complex structures.

Conditions with regards to the surroundings: these are important because of the consequences that neighbouring structures can have on the new structure or the consequences that the new structure can have on the neighbouring structures.

## Ground conditions

Ground water conditions: the pore water pressures should be investigated in order to avoid geotechnical failures, such as base heave in piping and excavations, and landslides due to high pore pressures.

## Regional seismicity

Influence of the environment: factors such as surface water, hydrology, changes on temperature, etc.

Limit states should be checked by one or more of the following: use of calculations, load tests and experimental models, observation method and implementation of prescriptive measures.

Three Geotechnical Categories (1, 2, and 3) should be introduced to establish geotechnical design requirements. The Geotechnical Category should be defined prior the geotechnical investigations and it should be checked and changed at each stage of design and construction, if it is necessary.

### **4. 4. 2. Geotechnical Categories**

Eurocode 7 introduced a system of three geotechnical categories (category 1, 2, 3). The selection of a category for a structure is based on the level of complexity of a design. The Highways Agency (2008) points that the categories based on the degree and complexity of geotechnical risk in geotechnical design. Geotechnical hazards and the vulnerability of the structure to specific hazards are the two factors of the geotechnical risk function. Geotechnical hazards are related with the ground conditions,



groundwater, environment and seismicity factors, and vulnerability with the structure and surroundings factors. Table 4. 1 presents the different levels of complexity for these factors in the different categories and the related geotechnical risks.

## **Factors to be considered**

### **Geotechnical Categories**

#### **GC1**

#### **GC2**

#### **GC3**

Geotechnical hazards

Low

Moderate

High

Ground conditions

Known from comparable experience to be straightforward. Not involving soft, loose or compressible soil, loose fill or sloping ground.

Ground conditions and properties can be determined from routine investigations and tests.

Unusual or exceptionally difficult ground conditions requiring non routine investigation and tests.

<https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>

## Groundwater situation

No excavations below water table, except where experience indicates this will not cause problems.

No risk of damage without prior warning to structures due to groundwater lowering or drainage. No exceptional water tightness requirements

High groundwater pressures and exceptional groundwater conditions, e. g. multilayered strata with variable permeability

## Regional seismicity

Areas with no or very low earthquake hazard

Moderate earthquake hazard where seismic design code (EC8) may be used

Areas of high earthquake hazard

## Influence of the environment

Negligible risk of problems due to surface water, subsidence, hazardous chemicals, etc.

Environmental factors covered by routine design methods

Complex or difficult environment factors requiring special design methods.

## Vulnerability

Low

Moderate

High

Nature and size of the structure and its elements

Small and relatively simple structures or construction. Insensitive structures in seismic areas.

Conventional types of structures with no abnormal risks

Very large or unusual structures and structures involving abnormal risk. Very sensitive structures in seismic areas

Surroundings

Negligible risk of damage to or from neighbouring structures or services and negligible risk for life

Possible risk of damage to neighbouring structures or services due, for example, to excavations or piling

High risk of damage to neighbouring structures or services

Geotechnical risk

Low

Moderate

High

Source: Orr and Farrell (1999)

### **Table 4. 1 Geotechnical Categories related to geotechnical hazard and vulnerability levels**

Some of the main features of each category are summarized below.

#### Geotechnical Category 1

Category 1 contains only small and simple structures. The fundamental requirements of EC7 may be satisfied only on the qualitative and experience geotechnical investigations. There is a negligible risk for life and property. The design of structures of this category requires person with appropriate comparable experience. Some examples of structures of category 1 are structures with maximum design column load 250 kN and maximum design wall load of 100 kN, retaining walls and excavation which does not exceed the 2 m and small excavations for pipes and drainage (Orr and Farrell, 1999).

#### Geotechnical Category 2

Category 2 contains foundations and types of structures with no abnormal risk or loading conditions, or unusual difficult ground. The fundamental requirements are satisfied using quantitative geotechnical data and analysis. The design of structures of this category requires a qualified person with appropriate geotechnical experience and knowledge, normally a civil engineer. Category 2 uses routine procedures for laboratory and field tests, for design and construction. Examples of structures for this category are considered the pile and spread foundations, the walls, the retaining

structures, the embankments and earthworks, the tunnels, the ground anchors, etc (Orr and Farrell, 1999).

### Geotechnical Category 3

Category 3 contains structures that are not included in categories 1 and 2. These structures can be very large and unusual structures, exceptionally or unusually difficult structures or ground conditions in highly seismic area. The design of structures of this category requires an experienced geotechnical specialist like a geotechnical engineer. Some examples of this category are very large buildings, large bridges, tunnels in highly or soft permeable ground, embankments on soft ground and deep excavations (Orr and Farrell, 1999).

#### **4. 4. 3. Limit State design philosophy**

Eurocode 7 is based on the limit state design philosophy. In this limit state design the performance of the whole or part of the structure is described and it is referenced to a set of limit states. Beyond these limit states the structure fails to meet its design requirements of being sufficiently durable, having an insignificant risk of collapsing, deforming and endangering life because of some shortcomings (Orr, 2000).

The limit states are divided into two: ultimate and serviceability limit states

#### Ultimate Limit States (ULS)

Ultimate limit states are situations that involve safety such as the danger of people, the collapse of the structure, the economic loss or any other type of

failure (Orr, 2000). The design situation in a ULS calculation with low risk of failure is achieved by using a set of partial safety factors to increase the loads effects for the ULS design action effect,  $E_d$ , and another one set to decrease the ground strength parameters or resistance for the ULS design resistance,  $R_d$ . The following condition must be satisfied in order to confirm that the occurrence of a ULS is unlikely:  $E_d \leq R_d$

The probability of occurrence of ultimate limit states is low for well designed structures (Orr and Farrell, 1999)

### Serviceability Limit States (SLS)

Serviceability limit states are situations where the structure may not be able to meet its specified requirements. The design situation in SLS calculation is achieved by using design values of the loads and soil deformation properties which are equal to the characteristic values. The ground deformation properties and partial factors on the loads are equal to 1. Some examples of serviceability limit states situations are the deformations, vibrations, local damage and settlements of the structure in its normal use. The probability of occurrence of serviceability limit states is higher than ultimate limit states. The following condition must be satisfied in order to confirm that the occurrence of a SLS is unlikely:  $E_d \leq C_d$

Where  $E_d$  is the design value of the action effect and  $C_d$  is the limiting value of the deformation of the structure in a serviceability limit state (Orr and Farrell, 1999).

The limit state design philosophy adopted in Eurocode 7 is important to geotechnical design because it refers in all possible types of failure and it verifies that no relevant limit state is exceeded for each design situation. According to Eurocode 1, the situations in which a structure fulfills its functions are the design situations. These situations may be transient, persistent or accidental. The transient situations happen in a period shorter than the life of structure and their probability of occurrence is high. The persistent situations happen during the working life of the structure and are situations of normal use. Lastly, the accidental situations are exceptional cases such as fire, explosion, etc (Orr and Farrell, 1999).

The above two checks are used to ensure that the risk of failure by serviceability or ultimate limit state is adequately low for each type of design situation.

#### **4. 4. 4. Four ways of carrying out geotechnical design**

Eurocode 7 adopts four design approaches as follows:

##### Use of calculations

This approach is the most common in geotechnical design. Eurocode 7 requires that this method shall explain the behavior of the ground for the limit state. This is the reason why different and separate calculations should be used in the check of ultimate and serviceability limit states. The ultimate limit states calculations involve analysis of a mechanism using ground strength properties and the serviceability limit states calculations involve analysis of deformation, ground stiffness and compressibility properties.

Design using calculations shall be used in conjunction with partial factors to <https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>

make sure that the risk of failure, either for ultimate limit state or for serviceability limit state, is low. Imposed loads, displacements, properties of soil, rock or other materials, geometrical data, partial factors or other safety elements, calculations models, values of deformations, vibrations, crack widths are the basic components of a geotechnical design calculation (Eurocode 7-part1, 2004).

#### Adoption of prescriptive measures

This design approach involves conventional and more general conservative rules. It also gives attention to workmanship, maintenance and protection procedures, and control and specification of materials. Adoption of prescriptive measures in design is used when the design by calculations is not necessary, or to ensure durability against biological or chemical attack and frost action (Eurocode 7-part1, 2004).

#### Use of experimental models and load tests

In this approach the following features must be allowed for and considered: The differences between the actual construction and test in the ground conditions, the time effects and the scale effects. Sometimes the tests are carried out on a full or smaller scale models, or on a sample of actual construction (Eurocode 7-part1, 2004).

#### Use of an observational method

The observational method is used when the geotechnical behavior is difficult to predict. In this approach the design is reviewed throughout the

construction. Before the construction is started the acceptable limits of  
<https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>



behavior must be established, the possible behaviors must be assessed, and a plan of monitoring must be prepared to check if the actual behavior is within the acceptable limits (Eurocode 7-part1, 2004).

The approaches are selected based on the experience. Sometimes only one approach is used in a design, but in other cases these approaches can be used in a combination. One simple example is the design of pile; the pile resistance can be determined from load tests and the design of pile foundations can use calculations with the value of pile resistance. It is recommended to use more than one approach and experience, especially in local conditions and similar designs (Orr and Farrell, 1999).

#### **4. 4. 5 Characteristic Values and Partial Factors**

Before the induction of Eurocode 7, geotechnical design used the traditional methods based on overall safety factors and not on the limit states (Orr, 2000).

As mentioned above, Eurocode 7 is based on limit states which require the use of characteristic values of ground properties and partial factors to ground properties and loads and sometimes to the geometry of design to achieve the required safety. Kavvas, 2007, said: ' The characteristic values consist of ' preservative appraisals' which usually do not differ from the recent ' understandable appraisals'. Orr (2000) said: ' The characteristic values of a ground property are a cautious estimate of the value affecting the occurrence of the limit state'.

The characteristic values of actions must be calculated according to the EN 1990: 2002 and EN 1991. The characteristic values of permanent actions  
<https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>

(Gk) are calculated from the nominal unit weight of materials including water pressures. The characteristic earth pressures use characteristic ground properties, surface load and characteristic water pressures. The characteristic values of variable actions (Qk) are specified values or values taken from meteorological records (Eurocode 7-part1, 2004).

The characteristic value of a ground property is defined as an estimate of the value that affects the occurrence of limit state (mean value over the relevant volume of ground). The characteristic values of geotechnical parameters are calculated from the derived values and the results of field tests and laboratory. Derived values are values of ground parameters obtained by empiricism or correlation from measured results and theory (Orr and Farrell, 1999). Measured results are values obtained by tests. Eurocode 1-part 1 (2004) requires that these values should take into account the following:

The geological information and other background data from previous projects

The variability of the measured property values

The laboratory and field investigation

The number and type of samples

The ability of the structure to transfer loads from weak zones to strong zones in the ground (Eurocode 7-part1, 2004)

The characteristic values and partial factors are used to the limit state method to calculate the design values of material properties, geometrical

data and loads (Orr, 2000). Design values are values that are used in design calculations (Orr and Farrell, 1999). The design value of load ( $F_d$ ) is calculated using the characteristic value ( $F_k$ ) and the partial load factor ( $\gamma$ ) with the equation:  $F_d = \gamma F_k$ . The design value for material properties ( $X_d$ ) is calculated using the characteristic value ( $X_k$ ) and the partial load factor ( $\gamma$ ) with the equation:  $X_d = X_k / \gamma$  (Eurocode 7-part 1, 2004).

#### **4. 4. 6. Three different approaches to limit state design**

Eurocode 7 introduced three design cases (Cases A, B and C) in geotechnical design to ensure that the risk of failure in the structure and ground is low for different combinations of ground properties and loads. Eurocode 7 requires that the designs shall satisfy all the three cases. The three design cases are described below:

##### Cases A:

It deals with uncertainties in favorable permanent actions and unfavorable variable actions in cases where the strengths of the ground and structure are insignificant. The aim of this case is to protect the geotechnical sizing and structural design from the problems, especially from the gross displacement like hydraulic failure, overturning of structures, buoyancy, etc. It is also related with situations in which the equilibrium depends first on the weight and then on the soil strength and in which the main loads are often hydraulic forces (Orr and Farrell, 1999).

##### Cases B:

It deals with uncertainties in actions. The partial factors on actions are greater than 1 as the ground properties are not factored. The aim of this case is to protect the geotechnical sizing and structural design from the characteristic values of the unfavorable deviations of the actions. These values are equal to the ground properties. Case B also deals with the structural design of foundations and retaining walls but it does not deal with the structural strength of an element like slope design (Orr and Farrell, 1999).

Cases C:

It deals with uncertainties in material properties. The partial factors on ground properties are greater than 1. The aim of this case is to protect the geotechnical sizing and structural design from the characteristic values of unfavorable deviations of the resistances or ground properties. In this case the characteristic values are equal to the permanent actions. The variable actions are increased but they are smaller than characteristic values in case B. This case also deals with the determination of size of ground's elements like the size of foundations, the depth of retaining walls, etc. Furthermore it is related to situations where the strength of ground is involved like slope stability problems (Orr and Farrell, 1999).

#### **4. 4. 7. Geotechnical Design Report**

Eurocode 7 requires the presentation of a Geotechnical Design Report (GDR) after the design. This report presents the design calculations, the design results, the data used, the assumptions made and the results of the verification of serviceability and safety (Eurocode 7-part1, 2004). The level of

details of the GDR depends from the type and the complexity of the design.

It usually contains the following descriptions of:

The site and surroundings

The ground conditions

The loads and the limiting movements

The design values

The statements on the standards and codes applied

The statements on the acceptable level of risk

The geotechnical design drawings and calculations

The items that must be checked throughout the construction of a structure, the maintenance or the monitoring of the structure (Orr and Farrell, 1999).

#### **4. 4. 8. Geotechnical investigations and geotechnical data**

Section 3 of Eurocode 7 gives the general requirements for setting up geotechnical investigations and collecting geotechnical data necessary for design. These requirements provide a reliable estimation of the characteristic values of the ground parameters and an appropriate description of the ground properties. All the information collected from the geotechnical investigation, including the parameter values from the laboratory tests and field, and groundwater and geological conditions, are presented in a Ground Investigation Report (GIR). 6

Eurocode 7 requires that geotechnical investigations shall give all the necessary data. It shall give all the data about the groundwater conditions and ground at and around the construction site (Orr and Farrell, 1999). These data help to a reliable estimation of the characteristic values of the ground parameters and to an appropriate description of the ground properties. It also requires that geotechnical information shall include the history, morphology, hydrology, geology and seismicity of the site and shall be collected and recorded very carefully. Moreover this code requires the consideration of the variability of the ground. The performance and construction requirements of the structure are mandatory in the geotechnical investigations. It also requires that the geotechnical investigations shall be reviewed when there is new information as the geotechnical category is possible to change. 6

According to Eurocode 7, geotechnical investigations should be carried out in three phases; preliminary, design and control investigations. Preliminary investigations include walkover surveys, desk study of ground conditions, boreholes, probes and bits to get sufficient information. They are carried out in the planning stage. Design investigations include laboratory and field tests providing all the necessary information about the design of permanent and temporary works and identifying difficulties during the construction. Finally, the control investigations are carried out during the construction stage and required to check the actual ground conditions, monitor and maintain. 6

When planning field tests Eurocode 7 include requirements for the equipment, carrying out the tests, reporting and interpreting the results and obtaining the derived values. . 6

<https://assignbuster.com/geotechnical-engineering-and-eurocode-7-construction-essay/>

To identify and classify soils, Eurocode 7 requires that the samples shall be taken from every separate layer that influences the behavior of the structure and for organic soils from at least every 1 m in one boring (Orr and Farrell, 1999). 6

When planning laboratory tests Eurocode 7 include requirements for the way the specimens (parts of rock or soil samples used in laboratory tests) are prepared, the testing equipment, the reporting of the results, the evaluation of the results, the testing procedures, the laboratory testing programme and the obtaining of derived values. When the laboratory testing programme is carried out, code requires that the stratigraphy, the soil type, the geotechnical aspects and the type of structure shall be taken into account. It also requires that all soil samples should be checked before any laboratory test. 6

According to Eurocode the results of the geotechnical investigations shall be recorded in a Ground Investigation Report (GIR). All the geotechnical information, the derived values and the evaluation of the information shall recorded in the GIR. This report also underlies the Geotechnical Design Report (GDR), contains all the field and laboratory works and all the test methods used. 6

#### **4. 5. Implication of Eurocode 7 for practice in UK**

The implementation of Eurocode 7 in UK faces some problems. The design calculations contain many sources of uncertainty in actions, materials strengths, resistance of structural sections, derivation of action effects, etc

(Driscoll and Simpson, 2001). A mistake in calculations can be unforeseen in later stages.

## 4. 6. Summary

The main objective of this chapter is to explain the changes that Eurocode 7 causes to Geotechnical Design. It refers to the fundamental design requirements that must be satisfied by all the structures, to the limit state design philosophy, to the use of characteristic values and partial factors, to the use of three design approaches and three geotechnical categories. It also explains the four ways of carrying out the geotechnical design and the necessity of geotechnical design report. Moreover it briefly refers in the history of Eurocode 7, in its scope and structure.

Mr Ian pls ignore these references. It is not the final structure.

1. eurocode7-Part1

2. EN-1997-Eurocode-7-Geotechnical-design-article

3. Eurocode-part2

4. implication-of-eurocode-7-for-geotechnical-design-in-ireland-article-orr

5. presentation-kavvada

6. Geotechnical-design-to-eurocode7-book-orr

7. presentation-kavada

8. selection-of-characteristic-values-article-Orr



9. Eurocode-1

10-EN1997-EUROCODE7-Geotechnical-design-article

11-eurocodes-in-Britain-the-questions-Beal-article