DESIGN AND QUALITY CONTROL OF SOIL MIX WALLS FOR EARTH AND WATER RETAINING STRUCTURES

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ABSTRACT

In recent years, the Deep Mixing Method has increasingly been applied for the construction of earth and water retaining structures. From practice, it has been experienced that there is a real need to develop execution and design rules adapted to the function of the soil mix wall (retaining wall, water barrier, foundation solution or a combination) including the temporary or permanent character of the application. Based on the results of the BBRI Soil Mix project (2009-2013), a design approach has been developed in collaboration with the SBRCURnet. The present paper briefly discusses the principles of this design approach which takes into account the function of the soil mix wall and the characteristics of the soil mix material. The interaction between the soil mix material and the steel reinforcement can be considered in the calculations depending on the function of the soil mix wall. Design and quality control requirements are given in function of the application and take the lifetime of the structure into account. Durability aspects of the soil mix material are therefore considered in the present design approach.

Keywords: design, requirements, quality control, retaining walls, foundation solutions, cut-off walls

INTRODUCTION

Since several decades, the deep mixing method is used for ground improvement works. A more recent application is the use of soil mix as structural elements such as in the case of the earth-water retaining soil mix walls. Since 2000, due to the economic and environmental advantages of the method, this particular application has shown an amazing growth in Belgium and in the Netherlands. A typical excavation (16 m depth), realized with CSM (Cutter Soil Mix) panels, is shown in Fig. 1. For temporary applications, the questions related to the mechanical characteristics of the material, its permeability and its adherence with steel have been investigated with success within the framework of the BBRI Soil Mix project (2009-2013) (see Denies et al. 2012 for more details). The durability of the soil mix material remains a complex topic while permanent applications are more and more observed in practice. In order to define an obvious design approach, it was necessary to clarify the potential functions of soil mix walls and to establish the requirements related to their design and construction. The BBRI (in Belgium) and SBRCURnet (in the Netherlands) have therefore worked together to publish guidelines in the form of a handbook titled 'Soil Mix Walls' (publication foreseen in 2015). In this handbook, a methodology is proposed for the design of the soil mix walls for which the interaction between steel and soil mix can possibly be taken into account dependent upon the application. Each potential function of the soil mix wall is described (e.g. earth retaining wall, cut-off wall, etc.) and the temporary or permanent character of the application is always considered.

Fig. 1. Excavation realized with the help of an anchored CSM wall in Heverlee (Belgium)

Specific design requirements and quality control procedures have been formulated for each function. The purpose of the present paper is to illustrate the philosophy of this design approach considering the function of the wall, its lifetime and its quality control.

EXECUTION OF SOIL MIX WALLS WITH AN EARTH-WATER RETAINING FUNCTION

During the execution of the deep mixing method, the ground is directly mixed in place with a grout made of binder and water. The binder is generally composed of cement and admixtures. But another type of binder can be prepared in function of the circumstances (type of soils, special requirements etc.).

In order to realize an earth(-water) retaining wall, soil-cement columns or soil mix panels can be executed and placed next to each other, in a secant way. By overlapping the different elements, a continuous soil mix wall is formed. Steel H or I-beams are then inserted into the fresh soil mix material to resist the shear forces and the bending moments that occur during excavation of the building pit. In Belgium and in the Netherlands, the cement content varies from 250 to 500 kg per cubic meter of column or panel. The water-binder weight ratio ranges between 0.6 and 1.2.

For the execution systems in one shaft configuration (column system), one out of two individual soil-cement columns has to be reinforced with a steel beam for the purpose of ensuring the retaining function of the wall. For the execution systems in multiple shaft configuration, a larger spacing is generally considered. For the CSM panels, each panel is reinforced with two steel beams.

In Belgium and in the Netherlands, an installation depth of more than 20 m can be achieved. The diameter (D) of the soil-cement columns generally ranges from 0.4 to 0.6 m. The typical length of the CSM panel ranges between 2.2 to 2.8 m with a thickness of 55 cm. Geometric tolerances have been introduced in the guidelines for the overlap between the soil mix elements: minimum 6 cm or D/8 (shaft configuration or water retaining function) for the columns and 10 cm for the panels.

If the retaining wall is built to resist the earth and water pressures, the permeability of the soil mix material is a key factor. Although the deep mixing contractors often add bentonite to the injected grout when the soil mix wall only ensures a cut-off function, they have to keep in mind that, in the case of a retaining wall, the addition of bentonite not only results in a decrease of the permeability but it can also have a negative impact on the strength of the soil mix material.

LARGE-SCALE BENDING TESTS ON SOIL MIX ELEMENTS

In order to assess the transfer of the forces through the soil mix wall, the designers have to consider the interaction between the soil mix material and the steel reinforcement. Until now, the designers have always considered that the bending moments were fully supported by the steel beams as a result of the lack of knowledge on the real contribution of the soil mix material to the bending resistance of the soil mix wall. Hence, the soil mix material only ensured the role of the arching effect. In order to investigate this question, seventeen large-scale bending tests have been performed on “real-scale” reinforced soil mix elements (columns or panels) excavated from seven Belgian construction sites, with various soil conditions and for different execution processes (CVR C-mix®, Tubular Soil Mixing and CSM). The procedure followed for the realization of these tests and the results have been published in Denies et al. (2014) and Denies et al. (2015) with the following main conclusions:

- Determined by back analysis, the “real-scale” stiffness depends on the flexural bending moment applied to the soil mix element. It decreases with increasing flexural moment as a consequence of the progressive opening of the cracks in the soil mix material, as there is a progressive displacement of the neutral axis in the section during the test. In the range of the flexural bending moments supported by the soil mix wall, the “real-scale” stiffness is significantly larger than the stiffness of the steel reinforcement only.
- The maximal flexural moment applied during the test (the moment at failure) is a factor 1.8 to 3 times higher than the flexural moment corresponding to the yield strength of the steel beam only.
- The measurement of the stresses in the steel beams shows an efficient interaction between the soil mix material and the steel reinforcement: the yield strength was reached (measured) in the steel beam ($\sigma_{measured} = \sigma_{yield\ strength}$) at bending moments 20 to 70 % higher than without any contribution of the soil mix material.

The creep phenomenon was not considered in this study due to the limited duration (5 minutes) of the applied load steps during the test.

On the basis of these conclusions, a design methodology was developed to take the interaction between steel and soil mix into account for the assessment of the bending stiffness of the soil mix wall and for its structural design. Please note that this design methodology is in agreement with the principles of the different Eurocodes, the building codes for Europe.

DESIGN OF THE SOIL MIX WALLS WITH AN EARTH-WATER RETAINING FUNCTION

In order to design a soil mix wall with a retaining function, the designer has to consider the following steps in his design approach:

- the verification of the arching effect,
- the assessment of the bending stiffness of the soil mix wall,
- the structural design of the soil mix wall.

The main principles of these design stages are briefly discussed in the following paragraphs.

The following considerations are only valid for soil mix elements reinforced with a steel beam (reinforcement cages are not considered in the present design approach).

Verification of the arching effect

The first consideration of design concerns the verification of the arching effect. The earth and water pressures have to be transmitted to the steel beams by the soil mix material. Figure 2 illustrates the arching effect for a soil mix wall with an earth-water retaining function. The distance between the steel beams has to be limited to ensure the arching effect according to the principles of Eurocode 2 (EN 1992-1-1):

$$l_s < 3H \qquad [1]$$

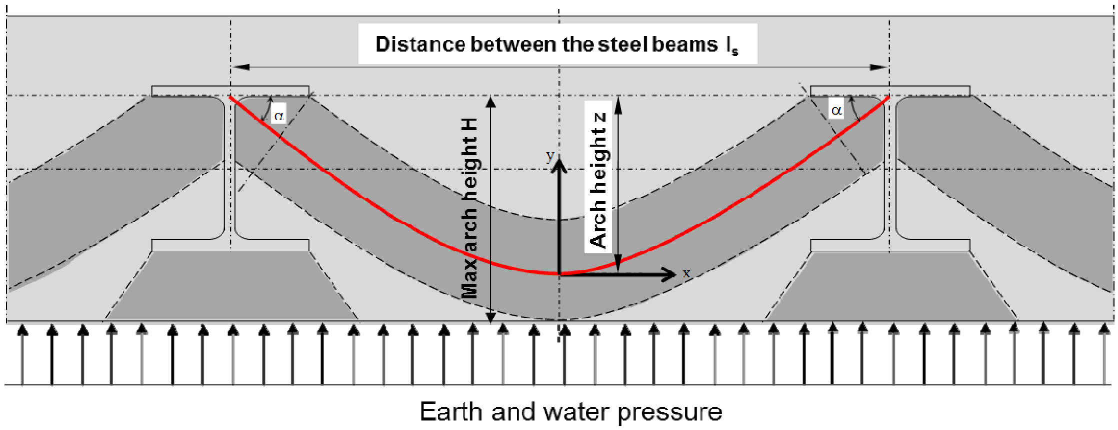

Fig. 2. Arching effect in the soil mix material

where l_s is the distance between the steel beams and H the maximal height available for the development of the arch in the soil mix material (see Fig. 2).

The arching behavior is verified according to Eurocode 2 (EN 1992-1-1).
The first step of the analysis is the computation of the dimensions of the arch (mainly its width) on the basis of geometrical considerations. This is realized by an iterative procedure varying the angle α of the arch by assuming a parabolic function for the central line of the arch (red line in Fig. 2).
In a second step, the development of the arching stresses arising in the soil mix material is then verified on the basis of a truss model according to Eurocode 2 (EN 1992-1-1). Figure 3 gives the truss model used to verify the compressive stresses in the soil mix arch. Figure 4 illustrates the development of such stresses with the help of a Finite Element Model for a virtual soil mix wall supporting the arching model.

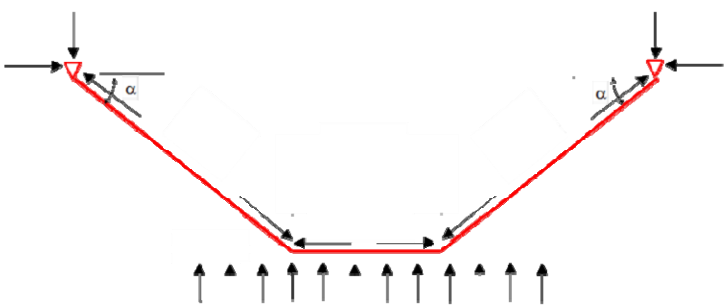

Fig. 3. Truss model for the verification of the arching effect in the soil mix material

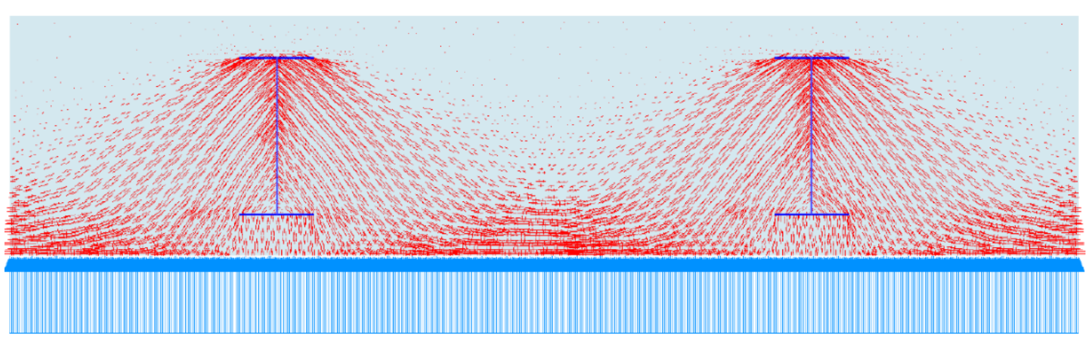

Fig. 4. Principal stress orientation in a virtual soil mix wall: illustration of the arching effect

For the temporary applications, the arching effect can always be considered. For permanent applications, this effect can be considered only if the soil mix wall is not directly exposed to the ambient air (influence of the wet/dry cycles and carbonation process) and if it is protected against frost (impact of the freeze-thaw cycles). A protection screen/barrier (side sheeting, coating, reinforced concrete or shotcrete etc.) has therefore to be applied on the exposed side of the soil mix wall. As the strength of the soil mix material is the governing factor of the arching effect, a long-term reduction factor will be applied to its UCS value in the case of a permanent application.

Assessment of the bending stiffness of the soil mix wall

A crucial point in the design of a retaining wall is the assessment of its bending stiffness EI. In practice, the designers introduce the value of the bending stiffness of the wall in their computational program for the purpose of assessing the bending moments and horizontal displacement. The control of the horizontal displacement is often an important design factor with regard to the job specifications. It is therefore important to apply a representative bending stiffness.

In the present design approach, several methods are proposed for the computation of the bending stiffness of the soil mix walls.

Based on a back analysis of the results of the large-scale bending tests, the first method considers a "real-scale" stiffness which takes into account the partial cracking of the soil mix material. The progressive cracking of the soil mix material is then considered under the application of the earth-water pressure on the wall. An iterative process is applied to determine the position of the neutral axis during the loading of the wall and the "real-scale" bending stiffness is computed as:

$$EI_{Real} = \frac{EI_1 + EI_2}{2} \qquad [2]$$

where EI_1 is the stiffness taking into account the section of the uncracked soil mix material (compression zone) and EI_2 is the stiffness considering the contribution of the section of the cracked soil mix material (tensile zone).

The second method consists in a simplified approach. The "real-scale" bending stiffness is determined as the sum of the stiffness of the reinforcement and the stiffness of the compressive zone of the soil mix section with the following assumption: the neutral axis is located in the middle of the steel beam. The "real-scale" bending stiffness becomes:

$$EI_{Real} = EI_S + E_{SM}\left[\frac{b_{c1}\left(\frac{H_{SM}}{2}\right)^3}{3}\right] \qquad [3]$$

where EI_S is the bending stiffness of the steel beam only, E_{SM} is the modulus of elasticity of the soil mix material, b_{c1} is the effective width and H_{SM} is the thickness of the soil mix wall. b_{c1} is computed as:

$$b_{c1} = \frac{L}{4} \qquad [4]$$

where L is the distance between two zero moment points along the wall. Moreover, b_{c1} has to be limited to the distance between the two steel beams: $b_{c1} < l_s$. In practice, b_{c1} is generally equal to l_s.

Equations [2] and [3] are given for an effective width. The use of the simplified method (equation [3]) generally results in values of bending stiffness 10 to 20% lower than those computed with the iterative procedure (equation [2]).

The characteristic value of the modulus of elasticity can be taken as the average value of the results of the tests for its determination. This average value has to be consistent with the UCS values of the soil mix material with regard to the existing correlations between both parameters (see Denies et al., 2012).

Using equations [2] and/or [3] for the assessment of a "real-scale" bending stiffness, the introduction of low and high values of bending stiffness in numerical programs is irrelevant. Different verifications can possibly be performed at different depths in function of the potential variation of the modulus of elasticity of the soil mix material with depth.

The contribution of the soil mix material to the bending stiffness of the soil mix wall can always be taken into account for temporary applications. In the case of permanent applications, the contribution of the soil mix material to the bending stiffness of the soil mix wall will be considered only if the soil mix wall is not directly exposed to the ambient air and if it is protected against frost. Moreover, a long-term modulus of elasticity ($=E_{SM}/2$) will be considered for permanent applications.

Structural design of the soil mix wall

Up to now, for the assessment of the forces in the soil mix wall (normal forces, shear forces and moments), the design only considered the resistance of the steel profile. But with regard to the large-scale bending tests and considering the results of *in-situ* pull-out tests performed on steel beams installed in real soil mix elements (see Denies et al., 2012), it has been shown that the soil mix material contributes to the structural resistance of the soil mix wall and could be taken into account at least for the temporary applications.

Considering the results of the large-scale bending tests and the principles of Eurocode 4 (EN 1994-1-1), a method has been developed to determine the bending moments taking into account the characteristics of the steel and soil mix materials (dimensions, mechanical properties etc.). The result of this method is presented in the form of design tables providing a value of bending moment as a function of the steel beam properties and the characteristic value of the UCS of the soil mix material. Table 1 gives an example of design table for a CSM panel (thickness of 55 cm) for a temporary situation (without long-term reduction factor applied on the UCS characteristic value). The contribution of the soil mix material results in a reduction of the stress in the steel beams. The bending moments obtained with this approach are 119 to 193% higher than those obtained with an "elastic method" only considering the yield strength of the steel beams.

The present method does not consider any limitation in terms of the adherence between the steel and the soil mix material. For the design of composite steel and concrete structures, Eurocode 4 (EN 1994-1-1) allows the consideration of the interaction between steel and concrete with a limitation of the design value of the adherence between both materials: $\tau_{rd} < 0.3$ MPa. For temporary soil mix applications, for which the interaction between steel and soil mix can be considered, the value of the maximal adherence between soil mix and steel is computed as follows:
τ_{rd} = min (10% of the UCS design value of the soil mix material; 0.30 MPa).
Taking into account this additional limitation, the reduction of the stress in the steel beam (and therefore the allowed reduction of the steel section) is ranging between 15 to 40 % (with regard to the case where only the steel beam is considered in the design with the "elastic method").
The interaction between steel and soil mix can only be considered in the structural design for temporary applications.

Table 1. Bending moment in a CSM panel reinforced with steel beams (type IPE S235)

Resistance of the soil mix wall in terms of bending moment (kN/L_{eff}^{γ})										
	IPE180	IPE200	IPE220	IPE240	IPE270	IPE300	IPE330	IPE360	IPE400	IPE450
M(Rd,a,el)†	33,2	43,4	56,7	71,9	95,8	125,3	158,7	202,7	257,0	336,0
M(Rd,a,pl)‡	37,8	49,3	64,2	81,3	108,2	141,5	179,2	228,8	291,0	382,0
M(Rd,2 MPa)*	46,2	58,4	74,3	92,2	120,4	155,0	193,6	244,1	307,2	398,8
M(Rd,5 MPa)	56,2	69,4	86,1	105,0	134,6	170,6	210,2	261,8	326,0	418,8
M(Rd,8 MPa)	64,2	78,0	95,4	114,9	145,4	182,4	222,7	275,1	340,2	434,2
Contribution of the soil mix material to the bending resistance in comparison with the “elastic method” The percentages are given without any consideration of a limitation of the adherence between steel and soil mix										
	IPE180	IPE200	IPE220	IPE240	IPE270	IPE300	IPE330	IPE360	IPE400	IPE450
M(Rd,a,el)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
M(Rd,a,pl)	114%	114%	113%	113%	113%	113%	113%	113%	113%	114%
M(Rd,2 MPa)	139%	135%	131%	128%	126%	124%	122%	120%	120%	119%
M(Rd,5 MPa)	(169%)	(160%)	(152%)	(146%)	140%	136%	132%	129%	127%	125%
M(Rd,8 MPa)	(193%)	(180%)	(168%)	(160%)	(152%)	(146%)	140%	136%	132%	129%

$^{\gamma}$Effective length = average distance between the steel beams
†M(Rd,a,el) is the bending moment computed with an “elastic method” considering only the steel beam resistance
‡M(Rd,a,pl) is the bending moment computed with a “plastic method” considering only the steel beam resistance
*M(Rd,2 MPa) is the bending moment computed considering a contribution of the soil mix material to the bending resistance with a UCS characteristic value of 2MPa for the soil mix material (a partial safety factor of 1.5 is applied on the characteristic value of the soil mix material to obtain the design value, no long-term reduction factor is considered)
Values between brackets should be limited to max. 140% due to the max allowed τ_{rd}

The consideration of this interaction is not allowed for structural design of permanent soil mix wall (creep is not considered for the establishment of Table 1). Hence, the computation of the bending moment of the permanent soil mix walls will only be based on the steel resistance of the steel beam.
In the present design approach, the shear forces in the soil mix wall are computed only on the base of the steel resistance in agreement with the principles of Eurocode 3 (EN 1993-1-1).

FUNCTIONAL REQUIREMENTS AND DESIGN SPECIFICATIONS

In the present design approach, requirements and quality control procedures are specifically given in function of the application of the soil mix wall.
Four types of retaining functions are considered:
• Function A: Temporary earth retaining wall
• Function B: Permanent earth retaining wall
• Function C: Temporary earth-water retaining wall
• Function D: Earth-water retaining wall with at least one permanent function

The design option related to the construction of a temporary earth retaining wall (FUNCTION A) is the possibility to consider the interaction between steel and soil mix for the calculation of the bending stiffness and for the structural verification of the soil mix wall (such as illustrated in the previous section). In general, for permanent earth retaining walls (FUNCTION B), the interaction between steel and soil mix will only be considered for the assessment of the bending stiffness of the wall (if the wall is protected against frost and is not exposed to the ambient air). The interaction between steel and soil mix should not be taken into account for the structural design of permanent soil mix wall.

For permanent retaining (and bearing) applications, it is required that the soil mix wall is protected by a protection screen/barrier (side sheeting, coating, reinforced concrete or shotcrete etc.). Furthermore the following aspects have to be considered: the creep behavior, the durability aspects of the soil mix material, the wall settlements and, if relevant, the effect of contaminated soils and the effect of potential seismic and dynamic loads. The protection of the steel reinforcement against corrosion is realized in agreement with the requirements of EN 1993-5.

The requirements and specifications related to the temporary earth-water retaining wall (FUNCTION C) are the same than for the FUNCTION A except that the soil mix wall has to present a permeability of 10^{-7} m/s and the soil mix material a permeability of 10^{-8} m/s.

In the case of an earth-water retaining wall with at least one permanent function (FUNCTION D), in addition to the requirements related to the FUNCTIONS B and C, the soil mix strength has to be high enough to resist internal erosion of the material in presence of groundwater flow (UCS > 0.5 MPa).

Two types of soil mix walls with a bearing function are considered in the design approach:

- Function E: Soil mix wall with a temporary bearing function
- Function F: Soil mix wall with a permanent bearing function

Here, one can consider that the forces are transmitted from the reinforcement to the soil mix material and from the soil mix material to the ground. In function of its embedment depth under the excavation level, the underground part of the soil mix wall is then considered as a shallow or a deep foundation. In the case of a deep foundation, the following aspects have to be regarded. No shaft resistance can be considered for the part of the soil mix wall above the excavation level. Below that level, shaft and toe resistances can be taken into account with regard to the nominal dimensions of the soil mix element. For the transmission of the vertical load to the ground, a maximal adherence between steel and soil mix is considered:
τ_{rd} = min (10% of the UCS design value of the soil mix material; 0.30 MPa). This adherence can only be considered if the UCS characteristic value of the soil mix is larger than 4 MPa (value currently subjected to discussion), if the wall is protected against frost and is not directly exposed to the ambient air and if special measures are taken to protect the reinforcement against corrosion (EN 1993-1-1). For permanent applications, long-term reduction factors are applied to the strength and stiffness of the soil mix.

Two types of cut-off walls are taken into account in the design approach:

- Function G: Temporary cut-off wall
- Function H: Permanent cut-off wall

The deep mixing contractors can add bentonite to the injected grout when the soil mix wall ensures a cut-off (low permeability) function. The addition of bentonite will result in the decrease of the permeability of the wall. Similarly to the water retaining function, the cut-off wall has to present a permeability of 10^{-7} m/s and the soil mix material a permeability of 10^{-8} m/s. If there are more severe requirements in terms of permeability, an impervious geotextile membrane can be installed into the fresh soil mix material during execution. For permanent applications, the upper part of the wall has to be protected against frost and the wet-dry cycles and the risk related to the presence of contaminants in the ground has to be mitigated. Influence of seismic loads has also to be taken into account for permanent cut-off applications.

QUALITY CONTROL (QC) OF THE SOIL MIX WALL

There are three important aspects with regard to the quality control (QC) of the soil mix wall: the execution monitoring, the geometric tolerances and the quality control of the properties of the soil mix material (strength, stiffness, permeability etc.). In the present design approach, the requirements related to the execution monitoring (i.e. the registration of the execution parameters) are in agreement with the European standard for the execution of the deep mixing method (EN 14679 – 2005). Tables 2 and 3 respectively present the geometric tolerances for the construction of the soil mix walls and for the positioning of the steel reinforcement. These tolerances are similar for the eight aforementioned functions (A to H). Nevertheless, stronger tolerances can be applied in function of the application. The most common way of characterizing the properties of the soil mix material is taking samples directly from the soil mix wall to be tested. The type and number of tests directly depend on the function of the soil mix wall and on the risk category of the structure. According to the philosophy of the Eurocodes, each particular structure corresponds to a risk category (RC) from 1 (low) to 3 (high). Table 4 illustrates the QC procedure for the case of a temporary earth retaining wall (FUNCTION A).

Table 2. Geometric tolerances for the construction of a soil mix wall

Soil-cement columns	**Panels**
Horizontal alignment of the soil-cement column within 25 mm (with a guide structure) or 75 mm (without any guide structure) of the planned location at the top of the columns	Horizontal alignment of the soil mix panel within 50 mm of the planned location at the top of the panels
Vertical alignment of the soil mix element within 100 mm of the planned location at the bottom of the elements	
Deviation with regard to the vertical inclination of the soil mix elements: 1.3%	
In the presence of cavities or large hard stones or in weak layers, large enlargements are unavoidable. Hence, local enlargements of 100 mm are tolerated.	

Table 3. Geometric tolerances for the installation of the steel beam in the soil mix material

Horizontal alignment of the center of the steel beam with regard to the center of the 'as-built' soil mix element at the top of the elements within 50 mm (or 25 mm with the use of a guide structure)
Maximal deviation for the horizontal alignment of the center of the steel beam with regard to the center of the 'as-built' soil mix element: 50 mm
Maximal deviation for the vertical alignment of the steel beam in the soil mix element: 50 mm
Angle of rotation of the steel beam with regard to the soil mix element smaller than 5° (hor. plane)

Table 4. Quality control of the soil mix material for a temporary earth retaining wall (FUNCTION A)

Basic test campaign per representative zone of the site (in function of the soil layers etc.) Number of test: 1 core sample per 150 m³ with a minimum of 6 cores per representative zone of the site Type of test: UCS and visual analysis of the unmixed soft soil inclusions into the soil mix matrix Interpretation: UCS characteristic and design values, assessment of the volume percentage of unmixed soft soil inclusions into the soil mix matrix, modulus of elasticity **Deviation with regard to the basic test campaign** - Risk category 1 and risk category 2: when no interaction between steel and soil mix is considered: comparable experience[†] may be sufficient. - Risk category 3: Number of samples to be multiplied with a factor of 2 with regard to the basic test campaign

[†]comparable experience implies that data are available for a minimum of two applications with the same execution system in similar soil conditions

In function of the application, the number of test samples will be adapted: 1 core sample per 150 m³ with a minimum of 6 cores for the FUNCTIONS A, E and G and 1 core sample per 75 m³ with a minimum of 12 cores for the FUNCTIONS B, C, D, F and H. Permeability tests on core samples are required for temporary and permanent cut-off walls and in presence of a permanent water retaining function. *In-situ* permeability tests are required for permanent water retaining and cut-off functions of risk category 3.
Soil mix samples can horizontally be cored in the exposed side of the wall after (partial) excavation. For permanent bearing function, the full height of the soil mix elements has to be investigated.

SUMMARY AND CONCLUSIONS

In the present paper, the authors review the main applications of soil mix walls as applied in Belgium and in the Netherlands. A design approach is proposed taking into account the function of the soil mix wall (earth-water retaining, bearing and cut-off functions) and its lifetime (temporary or permanent application). Based on the results of seventeen large-scale bending tests performed on real soil mix elements, the present design methodology considers the contribution of the soil mix material to the bending stiffness of the soil mix wall (for the temporary walls and for the permanent walls with a protection barrier) and to its structural resistance (only for the temporary applications). Regarding this approach, a design table is given for a CSM panel reinforced with IPE steel beams. Bending moments are provided for a soil mix material respectively presenting UCS of 2, 5 and 8 MPa. The contribution of the soil mix material in the structural design of this CSM panel results in a decrease of the stress in the steel beams in comparison with an "elastic" method only based on the yield strength of the steel beams. Taking into account the requirements of EN 1994-1-1 (2005), the admissible reduction of the steel section is finally ranging between 15 and 40%. Similar design tables can be provided for soil-cement columns. In the last part of the paper, functional requirements and quality control procedures are briefly given in function of the application of the soil mix wall. It is important to note that this design approach has been developed in agreement with the principles of the different Eurocodes, the building codes for Europe.

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