THOUGHTS ON THE MIX DESIGN FOR SOIL MIX WALLS USED AS PERMANENT RETAINING STRUCTURES

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ABSTRACT

Since 2000, the use of soil mix walls for the construction of retaining structures has become increasingly popular in Belgium and in the Netherlands. In practice, however, each supplier of these walls had its own approach for the design and execution. There was a lack of generally accepted requirements and criteria regarding the soil mix walls. For this reason, designers and contractors have been asked to pool knowledge and experience with such structures. The result was published in 2018 under the form of the BBRI/SBRCURnet Handbook Soil mix walls, referred as the handbook in the present paper.
Nevertheless, if this handbook provides a lot of information regarding the durability of the soil mix material and requirements for the permanent soil mix walls, the readers find in this publication few information regarding the mix design that is generally considered by the practice as a trade secret. In the present paper, the authors still provide some practical thoughts regarding the compliancy rules for the mixing water and the types of cement/binder which can be used for permanent soil mix walls considering the potential degradation phenomena which can arise with time due to the nature of the concept.

Keywords: permanent soil mix walls, retaining walls, durability, mix design

INTRODUCTION

Today, soil mix walls are increasingly applied in practice as temporary or permanent retaining structures with several design functions (e.g. retaining, bearing, cut-off…). In Belgium, according to the handbook, permanent means that the lifetime of the wall is more than 2 years. For these permanent applications, the durability of the soil mix material must be regarded to guarantee that the design functions are insured during the lifetime of the geotechnical structure. The topic of the durability of the soil mix material includes several aspects. First, there is the question of the evolution and/or the degradation of the hydro-mechanical characteristics of the soil mix material with time (strength, permeability, pH etc.). Then, the durability of the soil mix material can also have an impact on the (rate of) corrosion of the steel beams integrated into the fresh soil mix material during execution to resist the shear forces and bending moments due to the pressure applying on the wall. And finally, there is also the question of the durability of the soil mix material executed in polluted grounds or in soils containing compounds which can have a negative impact on the development of its characteristics. In the soil mix process, potential contaminants and other compounds, e.g. chlorides and sulfates from salt water, are directly mixed with the injected grout and with the soil. They are therefore integrated in the soil mix matrix and their potential impact is more important than for cast-in-place or precast concrete piles only exposed to the contaminants along their shaft and base area.

The purpose of the present article is to identify some factors and phenomena influencing the durability of the soil mix walls, to summarize the corresponding measures foreseen in the handbook to protect the permanent walls (regarding the soil mix material and the steel beams) and to provide additional compliancy rules for the mixing water and the types of cements/binders that should be used for the construction of permanent soil mix walls. In addition, the last section of the article identifies aggressive compounds for the setting, the strength development and the durability of the soil mix material.

FACTORS AFFECTING THE DURABILITY OF THE SOIL MIX WALLS AND PROTECTIVE MEASURES FOR PERMANENT APPLICATIONS ACCORDING TO THE HANDBOOK

As underlined in Denies et al. (2015), two antagonistic phenomena play a role in the durability of the soil mix material. On the one hand, there is a long-term increase of its strength with the time due to the progressive hydration reaction often encountered with the cements/binders used in the practice of the deep mixing. On the other hand, there is a progressive degradation of the material observed with time due to several factors: the outward diffusion of the calcium cations Ca^{2+}, the carbonation process, the effect of potential wet/dry cycles on the soil mix material, the negative impact of potential freeze-thaw cycles and the influence of contaminants or specific deleterious compounds possibly present in the soil.

Even though the strength of the soil mix material may increase with time, i.e. after the realization of the unconfined compressive strength (UCS) tests, often performed after 28 days or two months in practice, for safety reason, *no favorable multiplication factors are admitted in the handbook for long-term applications*.

The first degradation phenomenon, the **outward diffusion of the cations Ca^{2+}** from the soil mix elements to the surrounding soil is due to the natural trend of a system in the presence of several elements to reach a chemical equilibrium. As graphically demonstrated in Ikegami et al. (2005), a decrease of the cations Ca^{2+} is generally observed at the boundary of the soil mix element and an increase of these cations is observed in the surrounding soil. Nevertheless, as the decrease of resistance due to this loss of Ca^{2+} is limited to the boundary of the soil mix elements, it is considered in practice that this effect is compensated by the long-term increase of the strength (Topolnicki, 2004). *In the handbook, no specific safety factor related to this diffusion of Ca^{2+} is added in the computation of the design value of the strength of the soil mix material.*

Another phenomenon influencing the durability of the soil mix walls is the **carbonation process** wherein the CO_2 from ambient air can react with the calcium hydroxide $Ca(OH)_2$ of the soil mix material (as for concrete) to form calcium carbonate $CaCO_3$. For concrete material, it is a well-known process. Carbonation is a slow and continuous process progressing from the outer surface inward but slowing down with increasing diffusion depth. According to the results of Guimond-Barrett (2013), in atmospheric conditions, carbonation of soil mix material is a slow process as well (e.g. penetration depth less than 1 cm after 180 days). The progression of the diffusion depth in the soil mix material seems to be approximately proportional to the logarithm of time. Furthermore, the rate of propagation inside the material depends on the age of the material at the time of exposition to the ambient air. The effect of carbonation on the soil mix material varies in function of the reference sources with a degradation (due to the increase of the porosity and permeability of the cementitious matrix) or a reinforcement (due to the creation of extra calcium carbonate) of the strength. The question of carbonation is maybe more relevant for the protection of the steel reinforcement against corrosion. A consequence of the carbonation is the decrease of the alkali character of the soil mix material, expressed by a decrease of its pH from 12.5 to values smaller than 9.5.
In consequence, in the handbook, it is recommended to not consider the soil mix material in itself as a corrosion protective measure/layer and to take specific protection measures as given in EN 1993-5 (protective coating, galvanization, cathodic protection, additional steel section that may corrode during the lifetime of the structure…). If a loss of thickness of the steel beams due to corrosion is allowed in the design, the corrosion tables from EN 1993-5 and National Annex will be used. Below the groundwater level – and in the presence of polluted and aggressive soils (including peat) – in the long term a loss of thickness of 0.3 mm per 25 years will be considered. The consideration of a loss of thickness as a mitigating measure is only applicable if the decrease of thickness does not affect the functionality of the soil mix wall during its lifetime.

When soil mix walls are used as retaining structures, one side of the wall is often excavated only a few days after the execution. As a result, the young soil mix material is exposed to the ambient air and to the weather variations (rain, sunshine etc.). In other words, the soil mix material is subjected to **wet-dry cycles**.

The degradation of the soil mix material is mainly observed during the drying phases. The evaporation of the water from the soil mix material prevents or limits the hydration/hardening process. Consequently, shrinkage is possibly observed with the emergence of cracks in the material resulting in a rapid decrease of its strength, which is irreversible in case of continuous drying. This degradation is accentuated by the fact that, the hardening period, during which the soil mix material is more sensitive to drying phases, is generally longer for the soil mix than for concrete regarding the characteristics of the binders typically used for the deep mixing and generally presenting higher rate of granulated blast furnace slag. In these binders, the slag reacts considerably more slowly than the alites $3(CaO)\cdot SiO_2$ of the Portland cements, and strength development is slower to an extent that increases with the proportion of the slag. This kind of degradation was observed for BBRI creep tests conducted on core samples in a chamber with relative humidity of 60%. In these conditions, shrinkage and cracking of the samples were noticed even for low stress levels (only due to the drying conditions) resulting in a strong reduction of strength and stiffness. For similar samples, in saturated conditions, no shrinkage/degradation was observed. If the degradation of the soil mix material by wet-dry cycles is probably more important at short term, when the hydration process is not complete, there is no certitude about the long-term resistance of the soil mix material against this phenomenon. *In consequence, according to the handbook, for permanent applications, exposure of soil mix material to ambient air should be prevented to avoid evaporation shrinkage and the resulting decrease in strength and stiffness over time. This is especially important in (strongly) ventilated zones (e.g. underground car parks), in which progressive degradation of the soil mix material could occur. The soil mix wall may be protected with a protection (concrete) barrier/wall, shotcrete, specific coating…* In the USA, FHWA (2013) stipulates that the exposed face of the soil mix walls should be protected with shotcrete, precast concrete panels, or other protection to provide for long-term durability of permanent excavation support.

As specified in the handbook, one should also avoid that (parts of) the soil mix wall being exposed to ***freeze-thaw cycles****. If one deviates from this point, one should be aware that, based on current knowledge, a risk is being taken and that it is necessary to take specific measures (minimum cement content, minimum compressive strength, maximum volumetric percentage of unmixed soft soil inclusions, creep tests, tests with freeze-thaw cycles, ...) and regularly conduct tests during the lifetime of the wall.* Freeze-thaw cycles are not only an enemy for the durability of the wall but also for its short-term efficiency. Just after execution, freeze can already present a risk for the soil mix preventing or limiting the hydration process. Freeze can also lead to a degradation by "bursting" or shedding of the soil mix surface with the freeze-thaw cycles. Figures 1 to 3 illustrate this phenomenon for a retaining wall made of secant soil-cement columns (60 cm diameter) executed in loamy sand with limited peat content, characterized by an average cone resistance (CPT) of 5 MPa. The execution was performed in November 2016 on a Belgian construction site. For the mix design, the type of cement was CEM III/A 42,5 N LA with a cement content of 245 kg/m³ and a Water/Cement weight ratio of 1.2 (-). The photos were taken a few days after excavation. The soil mix material is characterized by a UCS characteristic value, $f_{sm,k}$, of 1.57 MPa, obtained two months after execution and computed according to the handbook procedure. The UCS average value is 4.13 MPa.

On the long-term, for unprotected soil mix walls, the **freeze-thaw and the wet-dry cycles** lead, in several cases, to the progressive degradation of the surface of the soil mix material, year after year, as a consequence of the meteorological variations, in function of the seasons. Figure 4 illustrates two blocks cut in CSM panels (performed with the Cutter Soil Mix system), excavated from two construction sites in Belgium, and kept to observe the evolution of their surface state with time. The block on the left comes from a CSM panel executed in a loamy soil characterized by an average cone resistance (CPT) of 2 MPa (for the soil mix material: $f_{sm,k}$ of 1.05 MPa, UCS average of 4.03 MPa after two months of hardening, porosity of 55% and permeability of 4.11 10^{-11} m/s). The other block comes from a CSM panel executed in a quaternary sand characterized by an average cone resistance (CPT) of 14.5 MPa (for the soil mix: $f_{sm,k}$ of 7.76 MPa and UCS average of 11.09 MPa after three months of hardening). In both cases, the mix design was confidential. Considering the state of the two blocks in Fig. 4, we could simply conclude that sand-cement mixtures present better resistance than silt-cement mixtures. As explained hereafter, this is only partially true.

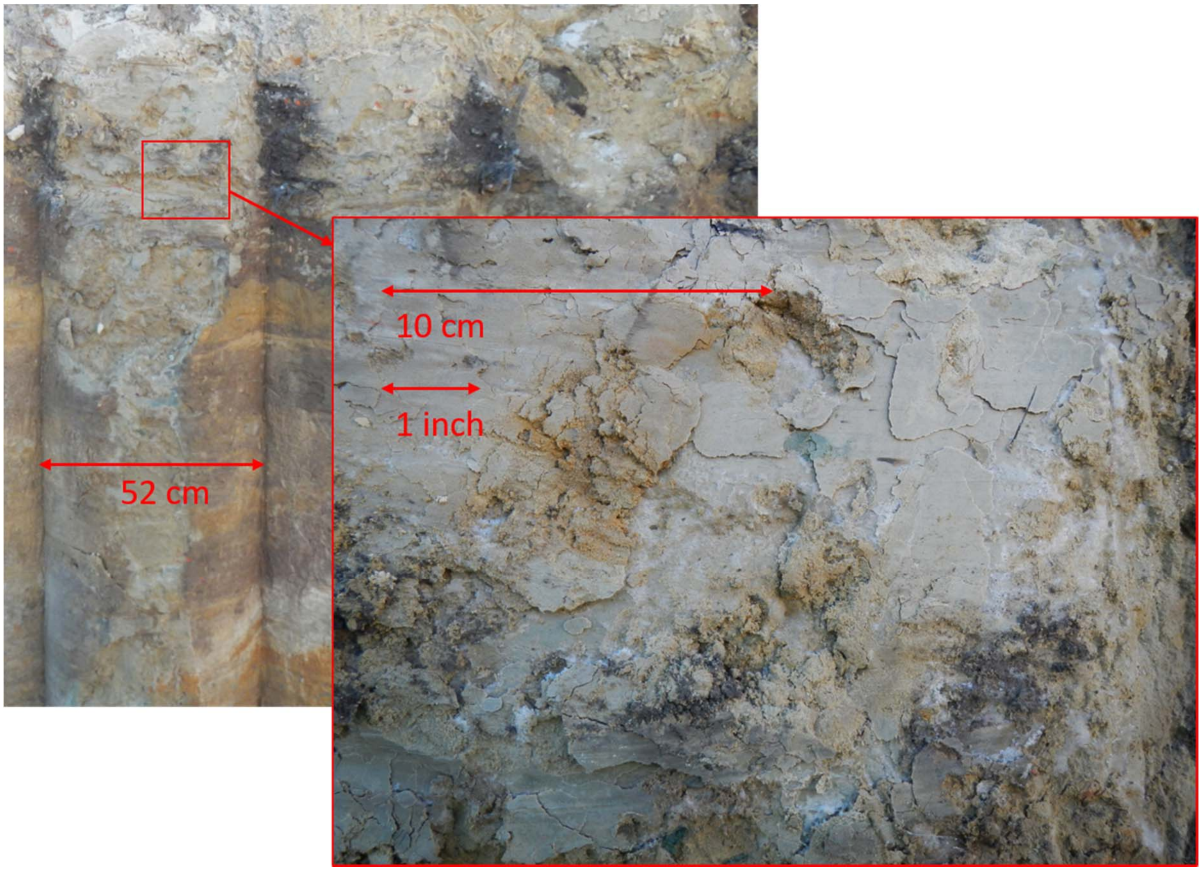

Fig. 1. Retaining wall made of soil-cement columns (60 cm diameter) subjected to freeze-thaw cycles – front view – the picture is taken on November 30, 2016, a few days after execution

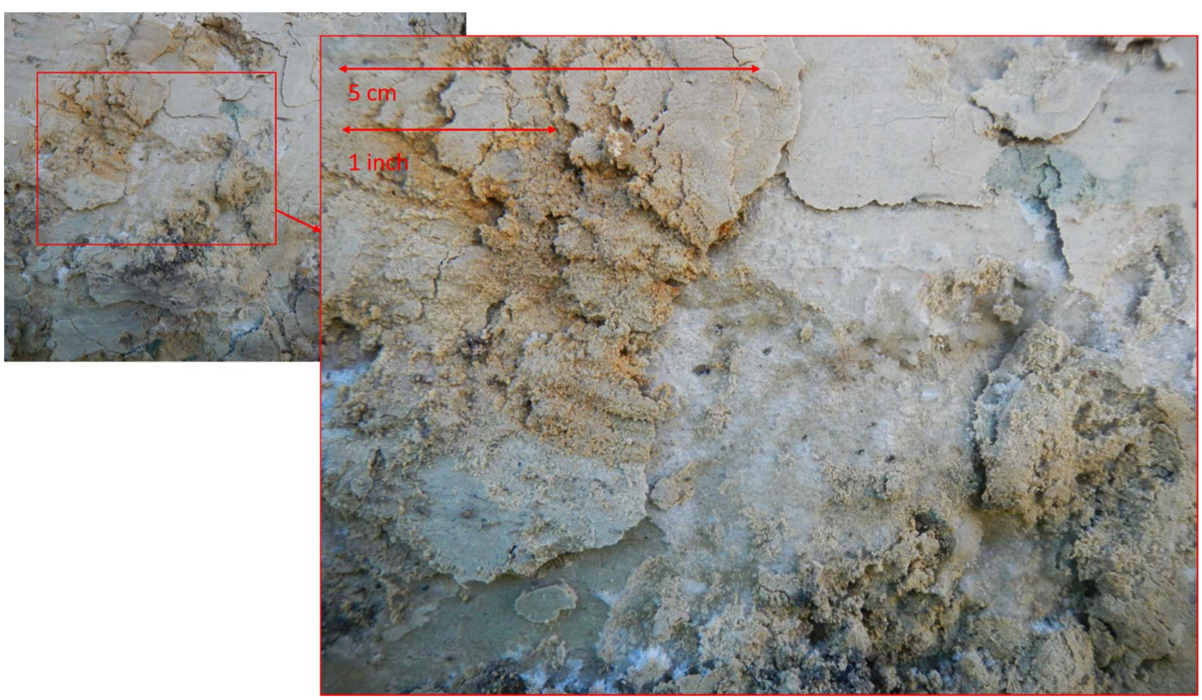

Fig. 2. Enlargement of the zone of the soil-cement column subjected to freeze-thaw cycles – front view – the picture is taken on November 30, 2016, a few days after execution of the column

Fig. 3. Illustration of the "bursting"/shedding process resulting from the freeze-thaw cycles – side view – the picture is taken on November 30, 2016, a few days after execution of the column

Fig. 4. Picture of two blocks cut in CSM panels excavated from two construction sites in Belgium - The picture is taken in October 2019, nine years after execution and excavation of the two panels

In sand-cement mixtures, the sand grains are generally insensitive to water. Therefore, it can be assumed that the strength development of the soil mix material is mainly governed by the effects of the curing conditions on the cement paste. Loamy, silty and clayey soils are sensitive to water. Drying and freezing have thus an effect on both cement and clay fractions of the soil mix material. In the experiments of Guimong-Barrett (2013), treated sand specimens offered better resistance to drying than treated silt specimens. The author explains that by the difference in porosity and considering the presence of water-sensitive clay minerals in the silt. Nevertheless, in practice, such degradations of the surface of the soil mix material are also noted for certain soil mix elements executed in sandy soils.
Actually, other factors must be considered to assess the long-term resistance of the soil mix material against these surface deterioration processes: the type of cement/binder, the binder content, the Water/Binder (W/B) ratio used for the execution and the mixing energy. As explained in Guimong-Barrett (2013), high durability will generally be obtained for a soil mix material presenting a limited porosity and a high strength.
The high porosity of the soil mix results from the high W/B ratio used for the execution, providing the required workability for the soil mix. It is therefore difficult to decrease it. Practical research on potential additives, such as superplasticizers adapted to the soil mix technology, is a real perspective for the practice. The required strength of the soil mix material will be obtained with a minimum cement/binder content (often based on the experience of the deep mixing contractor, more rarely given in the job specifications) and a minimum mixing energy limiting the strength variability.
As the mix design is generally considered by the deep mixing contractors as a trade secret, few information is available to fully understand the impact of the mix design on the durability of the soil mix elements. In Belgium, the philosophy of the quality assessment is mainly based on a post-control of the product by the way of in situ core samples. Special requirements regarding the mix design are rare. Therefore, in the handbook, the reader will find few information regarding the mix design for the construction of retaining walls. In the following paragraphs, the authors still provide some practical thoughts regarding the compliancy rules for the mixing water and for the types of cements/binders which can be used for permanent soil mix walls considering the aforementioned degradation phenomena.

COMPLIANCY RULES FOR THE MIXING WATER AND THE TYPE OF CEMENT/BINDER

In Belgium, there is currently no standard defining the mix design for the realization of soil mix elements. But trends progressively emerge from the practice.

The first compound of the mix is the **mixing water**. Potable water can always be used. Sometimes, water is available on site, e.g. when the construction site is located along an important river. If local authorization is obtained, this water can be pumped, in agreement with the local regulations, and mixed with the cement/binder in the mobile cement plant. Water can also be recovered from industrial processes. But before using it, the suitability of the water must be assessed. In absence of dedicated standard, European concrete standard EN 1008 (2002) - mixing water for concrete - is more and more used in Belgium. That is a first step to guarantee the setting and the short-term hydration reactions in the soil mix material.

The second step is the **determination of the type of cement/binder**. That choice will have an important impact on the durability of the soil mix material. A lot of compounds are already present in the ground(water) before the realization of the mix. Disregarding contaminants (such as hydrocarbons, heavy metals…), **chlorides and sulfates**, often present in the soil, in particular in nearshore zones with salt water, must be considered. The presence of chlorides is maybe more relevant for the question of the corrosion of the steel beams than for the setting, hardening or the durability of the soil mix material itself. But the sulfates can cause direct damages to the soil mix material.
After mixing, sulfates can react with some types of cement to form ettringite. The consequence of the formation of the ettringite mineral is the swelling of the soil mix matrix resulting in crack formation. Cracking leads to an increase of the macro-porosity of the soil mix matrix and creates preferential paths for the chlorides in the material increasing the risk of corrosion of the steel beams. The onset of the cracks and

the increase of porosity decrease the strength and the durability of the soil mix material and increase its permeability what is damaging in case of cut-off applications. In order to avoid the deleterious reactions with sulfates, it should be recommended to use a cement/binder suitable for underground applications and resisting to sulfate attacks. The sulfate content of the ground will govern the durability of the soil mix material if no adapted measures are taken for the mix design.

In Belgium, the cements are covered by the European standard EN 197-1. The Table 1 of this standard defines the 27 products in the family of the common cements (CEM I to V). The sulfate resisting cements have been included in the second version of this standard in 2011: CEM I-SR 0, CEM I-SR 3 and CEM I-SR 5, CEM III/B-SR and CEM III/C-SR, CEM IV/A-SR and CEM IV/B-SR.
In Belgium, high sulfate resisting cements are also defined in the National standard NBN B 12-108: CEM I-SR0 and CEM I-SR3, CEM III/B-SR and CEM III/C-SR, CEM V/A (S-V) HSR and SSC HSR.

In the NBN B 15-001, the National supplement to the EN 206-1, the European concrete standard, it is specified that for sulfate content higher than 600 mg/kg in the water or higher than 3000 or 2000 mg/kg (if the material is subjected to wet-dry cycles and if there is risk of capillary absorption of sulfates) in the ground, a high sulfate resisting cement must be used for the mix design. In absence of dedicated standard for the deep mixing, it is tempting to use these limits to determine the best-suited cement for each particulate soil mix field. However, in the deep mixing, sulphates are not only included in the surrounding soil but also in the soil mix matrix worsening the deleterious swelling phenomenon. A first precautionary principle could thus be the use of a sulfate resisting cement for the mix design of permanent soil mix walls.

Beyond the question of the sulfates, there is the risk of potential **alkali–silica reaction**. This is a swelling reaction that can occur over time in concrete or grouting type material between the highly alkaline cement paste and the reactive non-crystalline (amorphous) silica found in many common aggregates in moist conditions. For concrete, the risk of alkali-silica reaction can be limited regarding the choice of the aggregates. But, in the deep mixing, the soil is directly mixed in place with the cement/binder and the water. There is no control on the aggregates. For permanent soil mix walls, a second precautionary principle could be the use of a low alkali cement. Low alkali cements are not covered by the EN 197-1 (2011). In Belgium, low alkali content cements are listed in the NBN B 15-109: CEM I LA, CEM III/A LA, CEM III/B LA and CEM III/C LA, CEM V/A (S-V) LA and SSC LA.

For permanent soil mix walls, the aim would be the use of a cement combining the properties of the two cement families: sulfate resisting and low alkali; i.e. a cement:
- with a poor content of aluminum oxide, Al_2O_3, in which the formation of the tricalcium aluminate, $3(CaO)\cdot Al_2O_3$ has been replaced during the firing process, totally or partially, by the formation of tetracalcium aluminoferrite, $4(CaO)\cdot Al_2O_3Fe_2O_3$,
- with a high content of granulated blast furnace slag,
- with a low content of quicklime, CaO, source of cation Ca^{2+},
- with very low content of alkali Na_2O and K_2O.

Considering that the use of sulfate resisting and low alkali cements insure a better durability for the soil mix material, the following cements, produced by the companies affiliated to FEBELCEM (Belgian branch of the European Cement Association), could preferably be used for permanent soil mix walls in Belgium: HOLCIM CEM III/B 42,5 N LH HSR LA, CBR CEM III/B 32,5 N LH HSR LA, CBR CEM III/B 42,5 N LH HSR LA, CBR CEM III/C 32,5 N HSR LA, CCB CEM III/B 32,5 N-LH/SR LA and CCB CEM V/A (S-V) 32,5 N-LH HSR LA.
For the binders, it is more difficult to make a proposal, as they are not subjected to the same standards than cements. But considering the field experience and the information available in the technical sheets of the manufacturers, the following binders could also preferably be considered for permanent soil mix walls:
- the HOLCIM DORODUR 130, DORODUR 140 and DORODUR H50,
- the HEIDELBERGCEMENT GROUND-MIX H 160, GROUND-MIX H 161 and GROUND-MIX H 162.

These products are specifically developed for geotechnical applications in collaboration with deep mixing contractors.
For permanent nearshore applications (i.e. in sea water), a special attention will be brought to the type of cement/binder used for the mix design and to the respect for the design rules of the handbook regarding the protection of the permanent soil mix walls. In harbor projects, the use of galvanized beams is sometimes recommended by the port authority.

Despite the choice of a well-suited cement/binder for the mix, the protection of permanent soil mix walls – by a protecting (concrete) barrier/wall, shotcrete, specific coating…– remains necessary. For example, if one considers the cement HOLCIM CEM III/B 42,5 N LH HSR LA, present in the aforementioned list, this is a low alkali, sulfate resisting cement which seems suited for permanent soil mix application. Nevertheless, as specified by HOLCIM in the data sheet of the product, it is recommended to protect the concrete made with this cement type (thus, in the present case the soil mix) against the desiccation for the purpose of avoiding surface shedding and that to preserve the durability of the material "skin". According to the cement company, contact of the final stabilized product with **de-icing salts** must be avoided. Conclusion, if this cement is well-suited for permanent soil mix applications, protection measures of the soil mix wall, as specified in the handbook, must be applied to avoid degradation phenomena. The following paragraph illustrates this recommendation with a short case study.

CASE STUDY - ANALYSIS OF THE STATE OF A TEN-YEAR-OLD SOIL MIX SHAFT

In December 2008, a test silo (shaft) was performed on the site of the BBRI in Limelette (Belgium) by a Belgian deep mixing contractor. This retaining wall was made of 50 unreinforced soil-cement columns (63 cm diameter) installed in a secant way in such a way that they form a circular shaft with about 14 m depth and 7.5 m internal diameter. The purpose of the shaft was the realization of an excavation up to a depth of 11.5 m. The binder was the HOLCIM DORODUR H50 (clinker > 30% and granulated blast furnace slag < 60%). The binder content was 600 kg/m³ with a W/B weight ratio of 0.7 (-). Figure 5 presents the results of CPTs with the stratification of the test site. The water level is found at great depth (~ 40 m).
After realization of the excavation and characterization of the soil mix material by tests on core samples, the test pit was filled until 2 m depth and the soil mix wall was left, exposed to the meteorological conditions, without protection, during more than ten years. In November 2019, new core samples were cored in the above part of the wall at 1.5 m depth to investigate the evolution of the strength of the soil mix material after ten years of aging. The comparison is based on the average and characteristic UCS values obtained for the soil mix material executed in the quaternary loam. The UCS tests conducted in May 2009 on the cored samples resulted in a UCS average value of 13.8 MPa and a characteristic value $f_{sm,k}$ of 6.60 MPa. These UCS tests were performed on 28 core samples cored at depths ranging between 1.5 and 5.5 m. Considering only the results obtained on the 7 samples cored at a depth of 1.5m, these two values were respectively 11.44 MPa for the average UCS value and 7.17 MPa for $f_{sm,k}$. The new UCS tests were performed in November 2019 on 18 soil mix samples cored at 1.5 m depth. These tests result in an average UCS of 10.77 MPa and a $f_{sm,k}$ of 5.76 MPa. The carbonation depth (phenolphthalein test) varies between 2 and 5 cm (after ten years). Regarding this observation, the recommendation of the handbook to not consider the soil mix material as a corrosion protective layer and to take specific protection measures as given in EN 1993-5 seems to be legitimate. Porosity tests, performed by absorption of water by immersion, have been conducted in December 2019 resulting in porosity values around 45 %. That is a median porosity value regarding the set of data available for the soil mix material in the literature (cf. handbook, p. 339).
Despite the use of a suited binder and the relatively good results obtained for the UCS, the visual analysis of the surface of the soil mix shaft clearly indicates the progressive degradation, by bursting and shedding, of the soil mix material subjected to numerous wet-dry and freeze-thaw cycles during the last ten years (see Fig. 5 – below). Perceptible degradation depth (i.e. variable orientation cracks in the soil mix matrix) is generally ranging between 3 to 5 cm. Due to the progressive degradation of the surface of the material, a gradual decrease of the diameter of the soil-cement columns is thus observed with time.

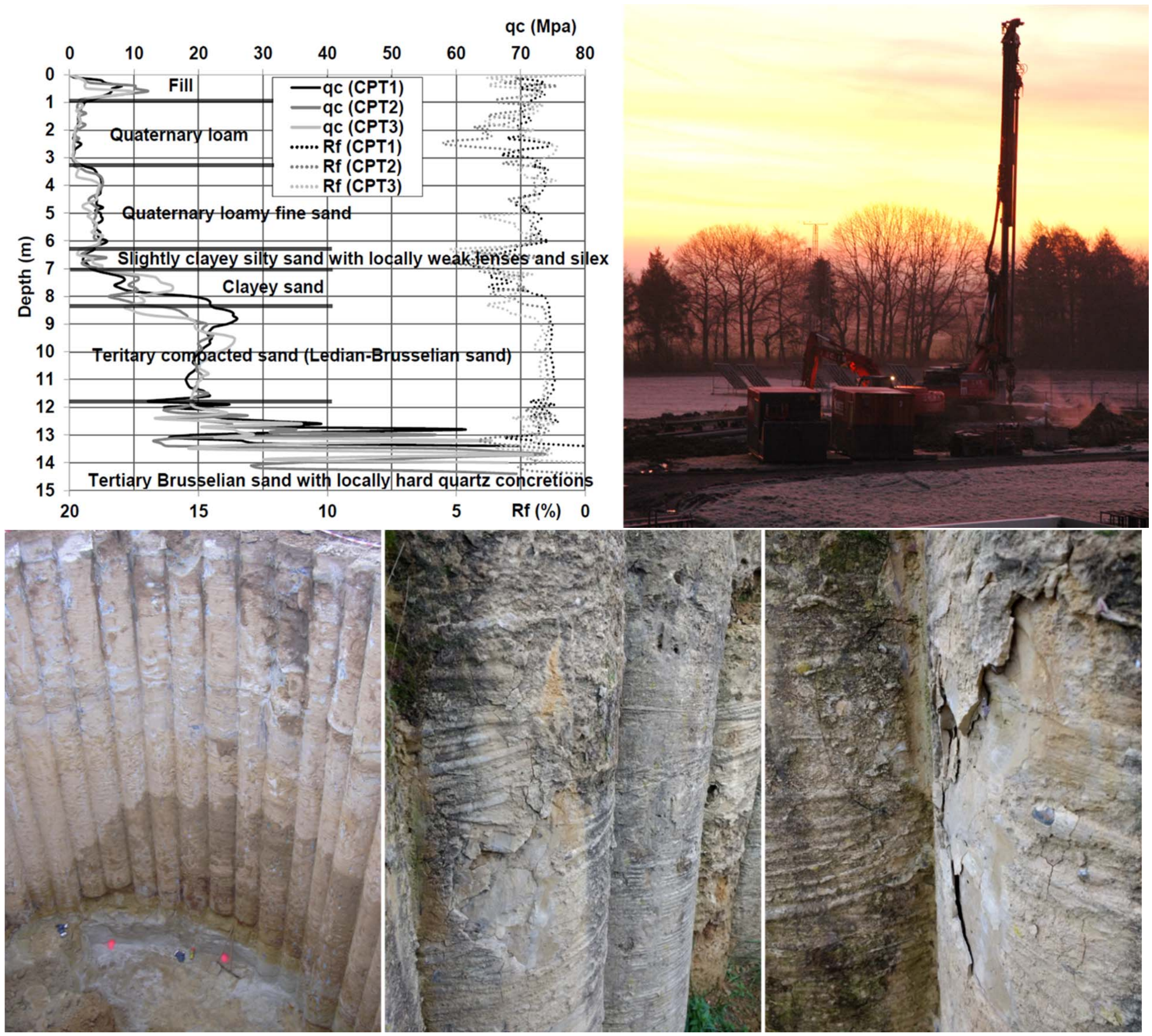

Fig. 5. Soil mix shaft installed in the site of the BBRI in Limelette in December 2008
Above: left - results of the electrical CPTs with the site stratification, right – deep mixing job
Below: left – excavated shaft (photo taken in February 2009), right: degradation by successive bursting and shedding of the surface of the soil mix material (photo taken in October 2019)

In practice, that means that, even with a suited binder and a mix design of quality (as for the present soil mix shaft), permanent soil mix walls must be protected, as indicated in the handbook, for the purpose of avoiding this decrease in diameter (for the columns) or in thickness (for the panels) and thus a progressive loss of the design function of the retaining wall. This is even more critical for retaining wall presenting a bearing function where the dimensions of the soil mix elements directly govern the bearing capacity.

INFLUENCE OF CONTAMINANTS ON THE DURABILITY OF THE SOIL MIX MATERIAL

As recommended in the handbook, in the presence of aggressive compounds in the soil, one should conduct a prior evaluation regarding their effect on the setting and the strength development of the soil mix material and on the corrosion of the steel beams. For permanent soil mix walls, the adhesion between steel and soil mix may be considered in the design only in the absence of contaminants that may affect the integrity of the soil mix material over time. Beyond the presence of sulfates and chlorides, hydrocarbons can have a deleterious effect on the setting and hardening of the soil mix material depending on their concentration. As reported in the handbook, several compounds may also affect the **setting** and the **strength development** of the soil-cement mixture playing the role of retardants (e.g. ZnO, PbO, As_2O_3, CdO…) or accelerators (e.g. $CaCl_2$ and $CrCl_3$). Concerning the impact of aggressive components in terms of **durability**, Table AA.2 from NEN 8005: 2008, the Dutch supplement of EN 206-1, provides an overview of aggressive compounds which can damage already-hardened concrete (acids, salts and alkalis, sulfates, petroleum – distillates…). In absence of equivalent for the soil mix material, this table can alternately be used.

CONCLUSIONS AND PERSPECTIVES

In this paper, a summary of potential degradation phenomena damaging soil mix walls is first given. Protection measures, as given in the BBRI/SBRCURnet handbook (2018), are highlighted for the respective degradation phenomena. Compliancy rules are proposed for the mixing water and the types of cement/binder used for the construction of permanent soil mix walls as retaining structures. These recommendations are suggested regarding the factors influencing the durability of these walls. Different cements and binders are identified for the mix design of permanent walls. Then, a case study demonstrates the importance to combine the use of a suitable mix design with the protecting measures of the handbook. In a near future, to improve our mastery of the durability of the soil mix material, one will must increase our knowledge of the fundamental relationship: type of (contaminated) soil – binder type, W/B ratio, binder content, mixing energy - UCS test results and observations regarding the durability of the walls (i.e. return of experience). During the lifetime of the structure, it is, for that matter, recommended to define a periodical monitoring (visual inspection) of the degradation of the soil mix material exposed to ambient air and of the steel reinforcements (cracking, corrosion products…) with a recommended periodicity as defined in the handbook.

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