From the maturity of encapsulation to the rise of reactive barriers

De la maturité des méthodes de confinement à la montée des barrières actives

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ABSTRACT: Short overview of the most versatile encapsulation methods, transferred from foundation engineering practice. Model examples of their combined application for remediation in complicated conditions of geotechnical/environmental problems.

RESUME: Revue des méthodes de confinement les plus souples, transférées de la pratique de technologie de sol. Exemples modèles d'application combinée de remédiation des problèmes géotechniques/écologiques en conditions compliquées.

1 INTRODUCTION

During the last three decades increasing number of projects for remediation of contaminated ground have used some method from a great family of encapsulation techniques as its solution. One reason is that more and more people involved in all stages of clean-up programs have realized the impossibility of a dream to get brown-fields totally changed to green-fields again, since our society had not enough financial resources. But we can always afford to make one important pragmatic step – to isolate the danger safely – which is often quite sufficient for further use of such treated brown-field in some regulated manner.

Another reason is that experience with an application of broad variety of encapsulation methods reached the level of comfort and reliability enabling any ground engineer for combining them towards an optimum result.

2 CIVIL ENGINEERING ROOTS AND METHODS ADAPTATION

Conventional civil engineering methods from water and road constructions, as well as from waste management, were in the beginning ready to employ them for encapsulation. Environmental engineering work, however, called for an adaptation of the technique's tools to new important factors and requirements imposed by physical, chemical and biological influences, not encountered before.

It is the groundwater flow that is the major factor of the environment. It had to be understood in more complexity. Electro-chemical gradient and phenomenon of diffusive flow were to be taken into analytic models, describing advection-dispersive transport of chemical solution in three-phase porous material. The analysis was to be followed at space of microstructure. Its conclusions therefore modified key factors of imperviousness, pollution retention and durability.

Reliability of installation techniques, operated industrially in foundation engineering every day, have successfully merged with the new research and development in the waste treatment engineering. But being responsible for controlling filtration, deformation and stability of the ground, ground engineers should be authorized to lead the teams of engineers in encapsulation projects.

3 MAIN ENCAPSULATION METHODS REVIEW

Present available methods, well-tried in practice, already provide versatile toolkit for any complex solution.

Encapsulation is usually carried out in mega-dimension by creating a large geo-containment box, as in a typical waste landfill on ground surface, by exploiting horizontal bottom and top barriers for it. For in-situ underground solution, it is created by exploiting natural bottom ground layer, where it is either sufficiently competent or improved, for example by jet-grouting. The box is then closed by vertical barriers in order to secure lateral cut-off, with final capping barrier on top.

In alternative encapsulation cases the geo-containment is getting in its geometrical shape to a rather amorphous block, while more developed foundation engineering techniques of soil improvement are applied for underground penetration, fixation and stabilization of pollution in-situ by grouting, soil-mixing etc.

Micro-encapsulation is applied in process of stabilization/solidification, which was already perfected in waste treatment stations for a broad variety of waste remains.

4 MODEL CASE HISTORIES

Quite a few demanding remediation projects have already been completed by combinations of these encapsulation methods, or even by complementing them with other foundation engineering methods. Examples below show success, even in extremely difficult conditions, when ground engineering approach prevailed in the project design and the works management.

4.1 SPOLANA chemical waste dump – consolidation before encapsulation

The ambitious project to build a new high-grade landfill atop an old dump of chemical waste, so that the horizontal capping barrier has double use as the bottom barrier of the new landfill, was enshrouded for fear of health safety risk for the works. The dump of loose, grainy chemical residue spread over 5 ha, in depth of 8 m, was deposited in chaotic manner without records during previous decades. It consisted of various remains of chemicals and ashes, with some buried barrels. The dry dump lagoon was positioned in sandy gravel sediments on the bank of the river Elbe, with its bottom flooded under groundwater table.

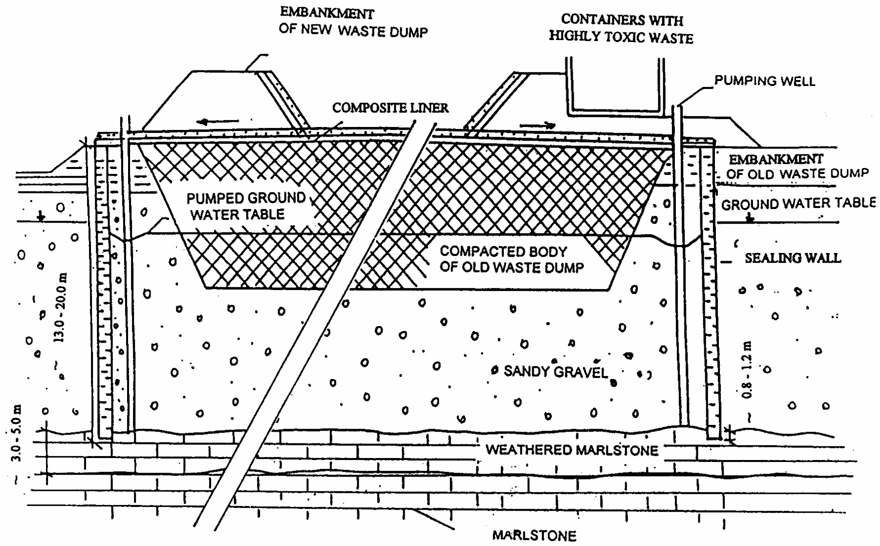

Figure 1. SPOLANA project – typical cross-section

First special supplementary investigation was undertaken, comprising retrospective analysis of waste deposition from aerial military photos, interviews of old eyewitnesses, etc., added with the network of CPT soundings.

A heavy dynamic consolidation method was then employed to consolidate the dump, or to improve its load bearing characteristics in the weakest spots by large diameter stone pillars. Treatment by pounder of 15 ton, falling from 20 m height, was controlled by an observational procedure, with detailed statistical evaluation by on-site computer analysis in real time. The works were closely seconded by chemical safety supervision. Ground improvement average ratio of 1,9 was reached, while average surface settlement was 0,567 m. Ground parameters for design requirements were proved by post-treatment CPT and by trial embankment instrumented loading test.

The treated dump was then , simultaneously with yet untreated adjacent liquid waste lagoon, closed into vertical cut-off diaphragm walls of 60 mm thickness. Marl layer, under-laying sandy deposit at 13–20 m depth, was tested and approved as sufficiently competent bottom for geo-containment. Special self-hardening slurry ECOSOL® was designed and used for the sealing barrier, with imperviousness characterized by filtration coefficient at n . 10^{-10} ms^{-1}. Clamshell grab technique was used for installation, trustworthy on the continuity and embedment of diaphragm wall.

PEHD geo-membrane of 2 mm thickness was embedded continuously 2 m deep at the crown of diaphragm wall so that the following bottom sealing of horizontal barrier of the new landfill could be interconnected with the vertical barrier of the geo-containment.

4.2 KEMA mixed waste dump - tar extraction before double-encapsulation

An open tar lagoon in the fields at the edge of the town spoken of its danger by its obtrusive smell. It had erupted to the surface during unsuccessful move to cover the wild dump of waste. Its history started many decades ago, when industrial waste tars and phenol sludge were dumped into 1 ha large, 8 m deep excavated pit, deserted after mining. Later the pit was flooded by ground water, then another waste was randomly dumped there and in its last decade the pit had been roughly filled by collected, but unsorted, municipal waste. A very special mixture of dangerous waste resulted there.

Ground engineering expertise for this project was urgent from the very beginning. Investigation of the dump surroundings gave a good picture about alternating sandy and clayey layers of the ground profile. A competent clay layer was proved at the bottom, at 9 to 17 m depth, and not too eminent danger of the already transferred contamination plume flow was found – ideal case for geo-containment – if it were not for the tar body existence.

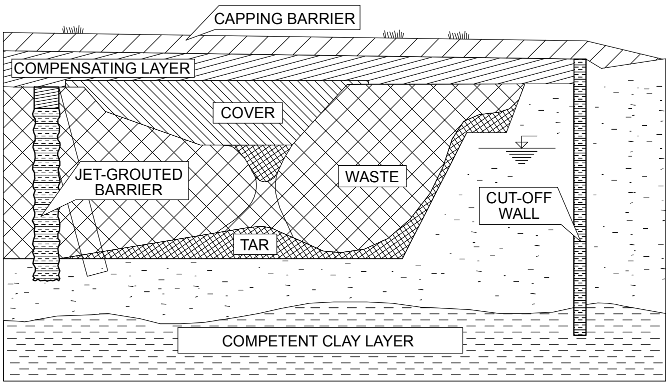

Figure 2. KEMA project – typical cross-section

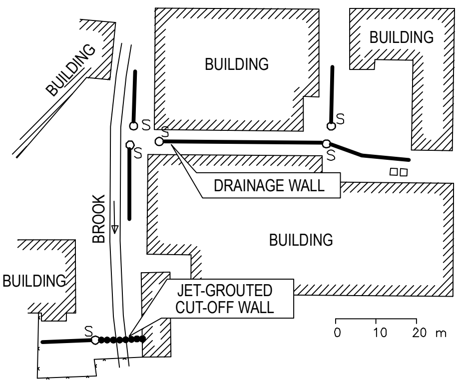

Figure 3. HULIN project – situation of drainage and cut -off barriers

Limited boreholes made through dump could not provide thorough information about its chaotic, heterogeneous, mega-structure. Only a retrospective analysis of its very special genesis could bring into existence a satisfying model for the solution. Its summary was supplemented by expert tests and judgment on hypothetical behavior of its elements, namely tar rheology, under encapsulation conditions. It was found that from about 4000 m3 of total initially deposited tar, some was dispersed through pit, but a body of about 1800 m^3 was closed in a pocket at the southern edge. The final shape of this body was created by diapiric phenomenon, with the open surface lagoon of 180 m^2 area.

The remediation was based on the idea of doubled geo-containment, internal and smaller one being designed for the part with the tar lagoon. The purpose of the internal geo-containment was first to provide separation and support for as much extraction of the liquid phase of tar as possible, by the jet-grouted vertical cut-off barrier through the waste body. Next step was to get out 600 m^3 of extractable tar and to transfer it away from site for further waste treatment by incineration etc. The remains of tar/waste mixture were then stabilized/solidified by mixing in-situ with selected admixtures. A final cover from lightweight concrete, reinforced with PEHD geo-net, was built over the internal geo-containment to assure uniform stability under overall outer capping.

The outer geo-containment employed cut-off diaphragm wall of 60 mm thickness, from purposely designed ECOSOL® self-hardening material. Top capping was made as an umbrella-like horizontal clay barrier, with gas and water drainage elements, covered with the re-cultivation topsoil layer.

4.3 HULIN deep drainage cut-off

Remedy project of de-contamination of PAU, BTEX, ClU etc. residues, trapped below existing buildings of the factory, was complicated by narrow factory streets and difficult ground, comprising variable layers of sandy or clayey soil. Pump-and-treat method soon reached its limit in wells positioning and extraction efficiency. Solution was then found in employment of 7 – 9 m deep drainage diaphragm walls of 600 mm thickness. So called “French drains” were carried out from two sorts of gravel, under temporary support of biodegradable polymer slurry.

The position of drainage wall has to be adapted to underground utilities and flow of groundwater towards natural collector of the existing brook, therefore in the place of the brook crossing it had to be combined with an elaborated jet-grouted cut-off barrier.

Thanks to consequence of the drainage wall employment, mainly by its totalizing filtration effect across soil profile, the collecting of contaminants was several times enhanced.

5 FURTHER DEVELOPMENT OF ENCAPSULATION METHODS

Present trend in encapsulation methods utilization drives them at an even more synergic and pro-active exploitation. It is evident in the reactive barrier system, which is ideal for long-time in-situ treatment, and suitable also for low or residual pollution. There are, however, still opened options to exploit these techniques for so called “hot-spot-pots”, some kind of in-place created reactor vessels for the purpose of very intensive short-time treatment, by subsequent chemical-biologic methods.

6 CONLUSION

Encapsulation methods have proved its technical competence, reliability and versatility on numerous remediation projects worldwide. Maturity of these methods, their speed and relative low cost, their potential for combinations, predestines them for further use in even more complex conditions.

It is important that ground engineers should take the leading position in encapsulation projects.

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