



Stabilization/Solidification (S/S) Technique and Its Applications in Saudi Arabia

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Abstract. The protection of the environment from hazardous pollutants associated with the soils contaminated with oil is a major concern in today's industrialized world, especially the developing nations. Therefore, there is a need to cure the contaminated soils to reduce the potential release of crude oil into the environment. The Stabilization/Solidifications (S/S) treatment process consists of the addition of cementitious binders to contaminated soils to form a slurry or liquid waste so that the contaminants from the soil can be prevented from affecting the environment. In this review, detailed discussion is presented on the stabilizers that were conventionally used for S/S treatment and tests for evaluating effectiveness of S/S treatment. In addition, advantages of the S/S technology is reported. Lastly, the background of soil contamination by oil spill in Saudi Arabia is addressed in this manuscript.

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1. Introduction

Stabilization/Solidification (S/S) can be defined as a clean-up technology that involves mixing soil with contaminated sludge and additives such as Portland cement, lime/fly ash, and cement/fly ash in order to immobilize the contaminants within the soil from being released into the environment, causing ground-water pollution (Paria and Yuet, 2006).

There are three technologies for in situ treatment: (1) Physical/chemical treatment technologies, (2) Biological treatment technologies, and (3) Thermal treatment technologies. There are several soil waste remediation techniques being used, but stabilization/solidification (S/S) seems to be more effective because it binds the compounds of hazardous waste streams into a stable insoluble form (stabilization) or entraps the waste within a solid cementitious matrix (solidification) (Wiles, 1987).

In the 1950's, S/S technology was originally developed but has been used recently as treatment. Moreover, S/S treatment mainly consists

of mixing the contaminated material with suitable stabilizers. Lime, cement, and other cementitious industrial waste materials are commonly used for S/S treatment. Stabilization refers to those techniques that reduce the hazard potential by changing the soil contaminants so that they become less harmful or less mobile (U. S. Army Corps of Engineers, 1995). Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. Furthermore, solidification changes the physical properties of a contaminated substance such as compressive strength, permeability, and encapsulation of hazardous constituents (U. S. Army Corps of Engineers, 1995).

This paper presents a brief overview of the stabilization/solidification (S/S) technique and its advantages and applications. It also explores the potential use of (S/S) in Saudi Arabia to explore the possibility of treatment of spoils.

1.1 Stabilization/Solidifications (S/S) Technology

Governmental agencies and individuals have adopted the S/S technology, and it has proven to be reliable. The S/S technique has been effectively used for treating and reclaiming soils contaminated by petroleum oil utilizing various chemical additives termed stabilizers, such as Portland cement, lime, fly ash, etc. The treated soil can be utilized in many ways such as landfilling and backfilling, road construction, making brick blocks, etc. There are numerous techniques for soil waste remediation that can be used for treatment, but S/S appears to be more effective and accurate. In addition, S/S technology has been described by the U.S. Environmental Protection Agency (EPA) as the greatest accessible technology for 57 RCRA (Resource Conservation and Recovery Act) listed hazardous wastes (Paria and Yuet, 2006). The EPA considers S/S to be an established treatment technology and has selected the technology at 25% of the Superfund program remediation sites, as depicted in Figure 1, due to its ability to treat different hazardous constituents within the same media and in situ. Furthermore, the methods for studying the effectiveness of the S/S process are physical, chemical, and microstructural.

1.2 Stabilizers Used in S/S Technology

Stabilizers used in S/S technology are either inorganic or organic, and the organic stabilizers should be safe for the environment, offered locally, and economically worthwhile. Initially, lime and cement were conventionally used for S/S treatment, but later on the utilization of waste materials having cementing properties for S/S treatment has become a common practice. Tuncan et al. (2000) reported that by using cement, fly ash, and lime to stabilize petroleum-contaminated soils, the addition of 5% cement, 10% fly ash, and 20% lime showed the better strength.

2. S/S Technology Advantages and Applications

In fact, the stabilization/solidification does not remove the contaminants from the soil. It only

prevents soil contaminants from spreading into the surrounding environment. There are many advantages of the S/S technology as listed below (Wiles, 1987):

- Good long-term stability, both physically and chemically
- Positive impact and comprehensive strength
- High resistance against biodegradation
- Relatively low water permeability
- Non-toxicity of the chemical ingredients used for S/S

Shah et al., 2002 reported that, by using cement, lime, and fly ash to stabilize oil-contaminated soils, the oil contamination of soil decreases the maximum dry density by 4%, cohesion by 66%, angle of internal friction by 23%, unconfined compressive strength (UCS) by 35%, and increases the liquid limit by 11%.

The results of tests using S/S technology indicate that the stabilization agents improve the geotechnical properties of the soil by way of cation exchange, agglomeration, and cementing. The improvement in unconfined compressive strength, cohesion, and angle of internal friction can be attributed to neo-formations, such as calcium silicate hydrates (C-S-H) that coat and bind the soil particles (Shah et al., 2002).

The treatment processes by S/S technology are designed to achieve one or more of the following:

- Improve the handling and physical characteristics of the waste
- Decrease the surface area of the waste mass, leading a reduction in the mobility of contaminants and blocking them
- Reduce the solubility of hazardous constituents in the waste
- Some of the applications of S/S technology for in-situ treatment of polluted soils and their ex-situ examples are as follows:
- Remediation of lead and petroleum contaminated soils at a Boston Brownfield site using cement-based S/S

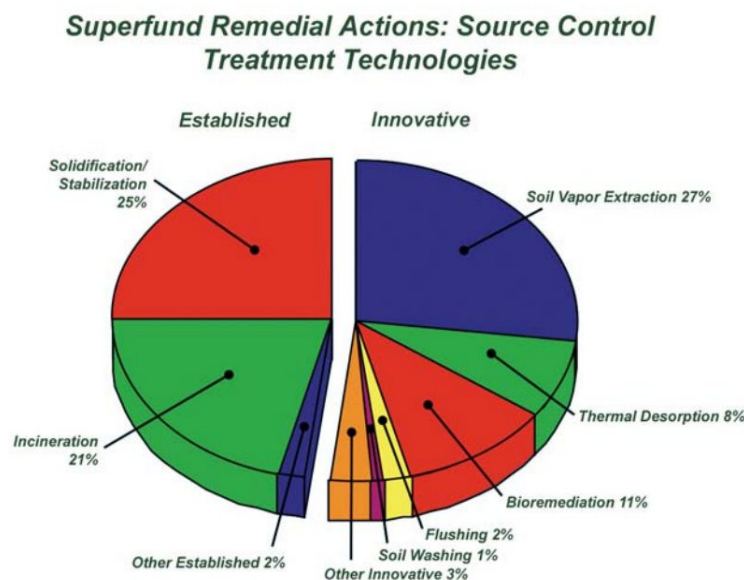


Figure 1: Frequency of S/S treatment use compared to other technologies (USEPA, 2001)

- Redevelopment of a former manufactured gas plant site as a research park in Cambridge, Massachusetts using cement-based S/S treatment
- Reuse of the S/S treated arsenic and creosote impacted soil at a former wood treating site as a base for pavement in Port Newark, New Jersey.
- Augusta manufactured gas plant clean-up using cement-based S/S in Augusta, Georgia.
- Reuse of New York Harbor sediments after S/S treatment of the sediments.
- S/S of contaminated soil at 90th South Battery Site, West Jordan, Utah.

burrows to depths exceeding 50 cm as shown in Figure 2.



Figure 2: Heavily oiled tidal flat along the northeast coast of Saudi Arabia shortly after the 1991 spill.

3. Soil Contamination in Saudi Arabia

Two decades ago, the northern half of the Arabian Gulf was hit by the heaviest and worst oil spill in history during which an estimated 8,100,000 cubic meters of oiled sediments remained within shoreline habitats ranging from exposed rocky shores to highly sheltered mud flats. Approximately 70% of the oiled sediments occur in sheltered habitats (mud tidal flats and salt marshes) mostly as oiled crab burrows with liquid oil remaining in the

Habitats exposed to the greatest amount of wave activity, such as the outer sand beaches, contain the smallest but a major amount of oil, which is buried by a few centimeters (about 20 cm) of clean sediment. Ecological recovery was lowest in mangroves and salt marshes, with over 80% of the upper intertidal zones having reduced species richness and a disturbed community structure, as depicted in Figure 3.



Figure 3: Sediment containing oil residue left over from the Gulf War oil spill (1991) and clean sediment deposited during the following 12 years.



Figure 4: The shoreline impacted by the Gulf War Oil Spill.

The shoreline spanning around 755 km up to the industrial city of Jubail in Saudi Arabia was

heavily polluted with the crude oil, posing a serious threat to the environment and flora and fauna in the sea. Recently, some companies have been assigned projects related to recovery of the flora and fauna using some specific techniques. The techniques adopted for restoration of the flora and fauna requires excavation of the contaminated soil along the shoreline for forming channels so that the seawater can move back and forth through these channels during high tides. As a result, a huge quantity of the contaminated spoil is being generated, which cannot be dumped in landfills without proper treatment.

The environmental pollution, which runs from Kuwait beaches to the shore borders of Saudi Arabia and is located near Jubail industrial area, is dangerous to the environment due to crude oil, as depicted in Figure 4.

As a result, the possibility of dumping the spoils in landfills is ruled out because of its huge quantity (approximately 500,000 m³) and also due to the complexity of the contaminated sediments. Therefore, it is essential to explore the feasibility of treatment of spoils using S/S technology for possible reuse of the treated sediments and the ability for engineering application such as using them as sub-base or base material for road construction, back fill, or construction material.

Ba-Naimoon (2013) studied the possibility of treatment of spoils using S/S technology to ensure either the safe disposal of the treated spoils or utilization of the treated spoils for engineering applications such as formation of sub-base or base courses in road construction. Three levels of the oil-contaminated soils (high, medium, and low) were collected from different locations and characterized using different laboratory tests. For S/S treatment, Portland cement and different cementitious waste materials, such as Cement Kiln Dust (CKD) and Limestone Powder (LSP), were used as alternative stabilizers. As a result, Ba-Naimoon (2013) reported that it is possible to use the oil-contaminated soils as sub-base material in flexible and rigid pavements, as shown in Figure 5.

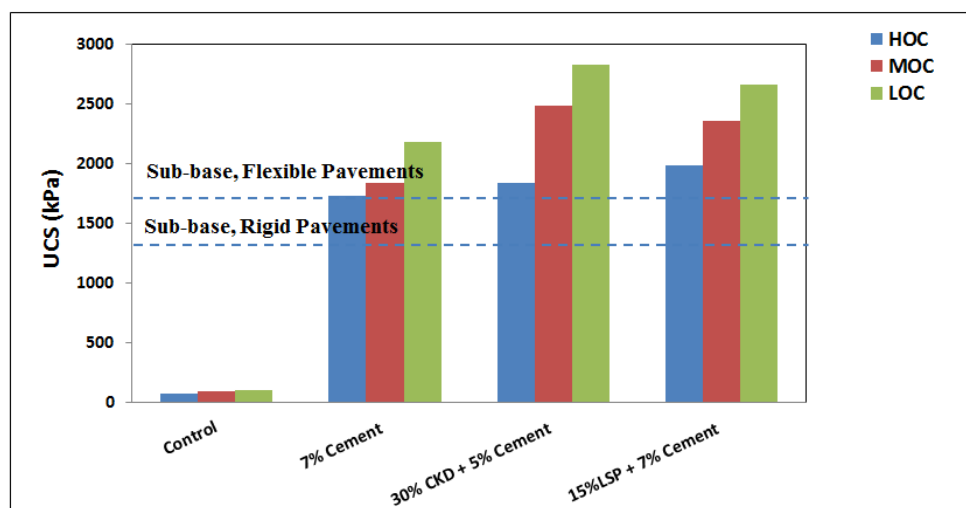


Figure 5: Suitability of UCS of S/S-treated HOC, MOC and LOC soils for road construction (Ba-Naimoon, 2013)

4. Conclusion

The S/S technique does not remove the contaminants from the soil. It only immobilizes the contaminant from having access to the environment, and it has been effectively used for treating and reclaiming oil-contaminated soils. In this research, S/S technology was used in the coastal area of Jubail in the Eastern Province of Saudi Arabia to treat three contaminated soils containing different oil spill levels (heavy, medium, and low). S/S technology is

considered an established treatment technology according to EPA standards, and it has selected the technology at 25% of the Superfund program remediation sites. It was found that treating the contaminated soil by using 7% cement and the combination of 30% CKD plus 5% cement and 15% LSP plus 7% cement to be used as a sub-base course in rigid and flexible pavements. As result, using the S/S treatment method showed improvement in satisfying strength and environmental criteria within EPA standards limits.

References

- Ba-Naimoon, M.S., (2013), A study on Stabilization/Solidification of Oil-Contaminated Soils. *Master's Thesis*, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia
- Paria, S. and Yuet, P.K. (2006), "Solidification/ Stabilization of Organic and Inorganic Contaminants using Portland Cement: A literature Review", *Environmental Reviews*, 14, 217-255
- Shah, S.J., A.V. Shroff, Jignesh V. Patel, K.C. Tiwari and D. Ramakrishnan (2002), "Stabilization of fuel oil contaminated soil-A case study". *Geotechnical and Geological Engineering* 21:415-427
- Tuncan, A., Tuncan, M. and Koyuncu, H. (2000), "Use of petroleum contaminated drilling wastes as sub-base material for road construction", *Waste Management and Research*, Vol. 18, pp. 489-505
- U.S. Army Corps of Engineers (1995), "Treatability Studies for Solidification/Stabilization of Contaminated Material". ETL 1110-1-158
- U.S.EPA (2001), *Innovative Treatment Technologies: Annual Status Report*, 10th Edition, EPA-542-R-01-004
- Wiles, C.C. (1987), "A review of solidification/ stabilization technology", *Journal of Hazardous Materials*, 14 (1987), 5-21