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A Review on The Binder Used to Remediate the Contaminated Soil byStabilisation Method

Mohamad Azim Mohammad Azmi[1]*, Noor Baizura Hamid[1], Mardiha Mokhtar[1], NoorulHudai Abdullah[1], SaifulAzhar Ahmad Tajudin[2], Shahiron Shahidan[2]

[1]Department of Civil Engineering, Center for Diploma Studies,
UniversitiTun Hussein Onn Malaysia, Muar, 84600, MALAYSIA

[2]Faculty of Civil and Build Environment,
UniversitiTun Hussein Onn Malaysia, BatuPahat, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: Soil is the essential for life, in the sense that they provide the medium for plant growth, habitat for many insects and other organisms, act as a filtration system for surface water, carbon store and maintenance of atmospheric gases. Unfortunately, soil is extremely exposable to contamination. It is necessity to treat the contaminated soils to reduce the heavy metal component in the soils. Thus, a review of the binder used to remediate the contaminated soil using the stabilization of contaminated soil with cement and waste material is chosen as it is widely applied method to sustain the environment. The method that were used is Stabilisation/Solidification (S/S) treatment process which consists addition of binders to strengthen back the soil to its formal state. It is shown by these studies that S/S remediation methods using various type of binders has made an attempt to solve this long overdue problem. These studies found that by using recycle material or waste material such as bagasse ash, rice husk, sea-shell, and biochar able to improve the quality of soil treatment.

Keywords: Contaminated Soil, Remediation Methods, Soil Stabilisation, Binder

1. Introduction

Soil is one of the most important elements. It is essential for life, in the sense that they provide the medium for plant growth, habitat for many insects and other organisms, act as a filtration system for surface water, carbon store and maintenance of atmospheric gases. Unfortunately, soil is extremely exposable to contamination. Soil contamination is mainly caused by industrial activities which

**Corresponding author: azim@uthm.edu.my*

generate waste and contaminants which seep into soil through direct disposal, emissions and other pathways. Soils can be contaminated with various chemical substance such fertilizers, pesticide, and other heavy metal. The thing that disrupt the most in soil is the compressive strength of the soil itself. Compressive strength is vital to withstand any load or force applied on the soil. The compressive strength of soil is important in nearly all geotechnical engineering designs because it is used for obtaining an estimate of the soil strength [1].

The protection of the environment from hazardous pollutants associated with the soils contaminated with oil is a major concerned in today's industrialized world [2]. The Department of the Environment (DOE) has described contaminated land as 'land which represents an actual or potential hazard to health or the environment as a result of current or previous use. The main factor that contribute to soil contamination is mostly because of man-made waste. Hence, it is necessity to treat the contaminated soils to reduce the heavy metal component in the soils. Thus, a review of a few binders use to remediate the contaminated soil using the stabilization of contaminated soil with cement and waste material is chosen as it is widely applied method to sustain the environment. The method that were used is Stabilization/Solidification (S/S) treatment process which consists addition of binders to strengthen back the soil to its formal state. This method is used in order to strengthen the weak contaminated soil which will be used in the construction project. Therefore, by reconstructing the formal state of the soil, any unwanted accident in the future could be prevented. This study is aiming to compare the result obtain by previous study on the binder used to remediate the contaminated soil by stabilisation/solidification method.

2. Binder use in Stabilisation/Solidification Method

In general, soil treatment becomes attention in a past few years. This is because, most of the pollution that occurs either water or air ends up in the soil. Therefore, researchers around the world are actively conducting studies related to soil remediation. Over the past few years, soil remediation using additives or binders such as cement have been widely used. However, the use of cement is said to have contributed to another pollution problem during the cement production process at the factory. Therefore, the researchers have tried various other materials to replace cement. The materials used usually have the same properties as cement. Among them, most popular are organic binders which known contain high fiber properties. In addition, the use of waste or by-product from agricultural processes. Therefore, **Table 1** summarizes the materials that have been used by researchers in treating contaminated soil by various polluting agents.

Table 1: Summarise of binder used in soil Stabilisation Methods

Researchers	Problems	Binder	Soil Type
Dauda et. al., (2018) (Nigeria)	Soils encountered seasonal volume change, generally covered with sesquioxide.	OPC & Periwinkle Shells	Lateritic Soil
Surjandari et. al., (2018) (Indonesia)	Having high-water content, has low strength and a large volume change.	Active lime & Egg Shell Powder	Fine Grained Soil
Cui et. al., (2019) (China)	Pulp processing during paper manufacturing generates wastewater contain polychlorinated organic compund.	Biochar	Contaminated wetland soils
Sadeeq et. al., (2015) (Nigeria)	Lateritic soil is mainly made of iron and aluminium compound and poor in humus which is essential for plant nutrients.	Bagasse Ash	Contaminated lateritic soil
Okagbue, C.O. (2007) (Nigeria)	Determination of the geotechnical properties of clay soil in its natural	Wood ash	Clayey soil

	state as well as when mixed with varying proportions of wood ash.		
Andavan&Pagadala (2020) (India)	Asphalt structure on poor soil sub grades show early bothers causing the premature failure of the asphalt.	Fly ash and Lime	Clayey soil
Xu, et. al., (2020) (China)	Replacing cement for soil stabilization because increasing cost and the industry waste has been increasing.	Sintered limestone ash	Soft soil
Andavan&Pagadala (2020) (India)	Clay soil hard to designing and processing by low bearing limit, high shrinkage and swell qualities and high dampness defencelessness	Fly ash and Lime	Clay soil
James (2020) (India)	Expansive soils have poor volume stability in the presence of water. The damage to structures built on expansive soil is well documented	Sugarcane press mud, lime	Expansive soil
Mokhtar et. al., (2016) (Malaysia)	High water content soil (clay soil)	Dust shells	Clayey soil
Kuzhali& Krishnan (2017)	Remediation of the problematic soil	Seashell powder (SSP)	Expensive soil
Liang&Wang (2014) (China)	Remediation of the problematic soil	Oyster Shell (OYS)	Clayey soil

A study by Ogundipe&Oyesomi [3] shows satisfactory outcome by using an environmentally safe material known as Periwinkle Shell Powder (PSP) on remediation the instability lateritic soil. The engineering experiments were carried out on lateritic soil stabilised with additions of PSP and OPC respectively (2, 4, 6, 8, and 10%). The result showed that cement steadily increased the maximum dry density (MDD) of laterite soil from 1875 kg/m^3 (2%) to 2294 kg/m^3 (10%) respectively. This result reflects an improvement of 22% of the poor situation in the MDD condition. The average MDD for sample containing PSP was reached at 6 percent (1974 kg/m^3), which reflects an improvement of 5.3 percent in soil MDD from the unstabilised condition. The optimum moisture content (OMC) rises from 13.65% to 13.83% for both stabilising agents and from 11.72% to 14.41 % for cement and PSP, respectively. The samples containing PSP reported a 5.6% increase in CBR value relative to OPC, which registered a 34% increase in CBR value. Accordingly, the study concluded that Periwinkle Shell Powder (PSP) could be considered a good stabiliser for clayey or laterite, and its uses as a stabiliser could also provide great relief to the pollution caused by its indiscriminate dumping.

In another study, Surjandari et. al., [4] investigated the effect of eggshell powder (ESP) on clay with high plasticity. The problematic soils at liquidity index of 0 – 1.25 are mixed with the ESP in various percentages of 0%, 10%, 15%, 20%. Several laboratory experiments were performed to analyse the effects of the mixtures, such as index properties, unconfined compressive strength and Scanning Electron Microscopy (SEM). The result shows that the liquidity index has an effect on the soil stabilized by ESP. The results of SEM tests show that the soil structure changes, it is dense on a mixture that contains 10% ESP. The researchers concluded that higher liquidity will cause to the lower of soil strength.

According to study conducted by Liqiang et. al. [5], organochlorine waste from papermaking has polluted the soil strata worldwide, and using appropriate binders such as biochar will help to improve soil pollution rate. On that purposed, a field study within 2014 to 2016 has been conducted to investigate the application of wheat (TriticumAestivum L.) straw biocharin the range of 0, 20, 40, and 60 Mg ha^{-1} to organic halogen-contaminated saline alkali

soil. The aim of the study is to analyse the usage of wheat straw biochar on stabilising the polluted soil. Result indicate that by adding biochar as a binder, the concentrations of absorbable organic halogens (AOX) in the soil is reduced and extractable organic halogens (EOX) in reeds by 9–94% and 14%–51%, respectively, and subsequently increased reed biomass by 1%–25%; these changes were related to the changes in different soil properties. This study concludes that the soil properties, which is organic functional groups, surface properties, and pH, were improved following the addition of biochar, and some changes were maintained at the highest level over time.

Next, Sadeeq et. al., [6] study the behaviour of the laterite soil which is rich in iron and aluminium oxides, formed by weathering of igneous rocks in moist warm climates. It is composed mainly of iron and aluminium compounds and poor in humus and essential plant nutrients such as phosphorus, nitrogen and potassium, but may contain large amount of quartz and kaolin. The study evaluated the effect of bagasse ash on the California bearing ratio of lateritic soil. The testing is done by mixing the soil with bagasse ash by 0, 2, 4, 6 and 8 % of total weight of dry soil and contaminating with used oil by 0, 2, 4, and 6 % of the weight of dry soil. The result shows that the liquid and plastic limits increased from 36.32 and 21.30 % respectively to peak values of 38.00 and 21.54 % at 2 % bagasse ash content for all oil contents. The maximum dry density (MDD) of the soil increased from 1.48 Mg/m3 for the control soil samples to peak value of 1.49 Mg/m3 at 8% bagasse ash content for all oil contents. The Optimum Moisture Content (OMC) increased at 18.5 % for the control soil samples and 19% for 2% and 4% bagasse ash contents and decreased at higher percentage of bagasse ash used. It can be conclude that the maximum dry density of the soil increased with increase in both oil and BA contents and Oil contamination resulted in reduced strength in lateritic soils and therefore, contaminated soils should be avoided in use as construction materials.

Furthermore, a study by Okagbue [7] shows that went using wood ash, the evaluation involved assessing the geotechnical properties of clay soil in its natural state as well as when combined with different wood ash proportions. This measured the ability of the wood ash to stabilise clay soil. The parameters tested included the particle size distribution, specific gravity, Atterberg limits, compaction characteristics, California bearing ratio CBR and the compressive strength. The CBR and strength tests were repeated after 28-day curing of the treated samples. Results showed that by incorporating wood ash, the geotechnical parameters of clay soil were significantly improved. The plasticity was decreased by 35%, while the CBR and strength increased by 23–50% and 49–67% respectively. The highest CBR and strength values were achieved at 10% wood ash mixed. The analysis shown that the curing periods has increased the strength of the clay treated with wood ash. Nevertheless, the increase in strength was short-lived as the strength decreased rapidly after 7–14 days. This finding indicate that while wood wash provides some of the beneficial effects of lime in the stabilisation of soil, such as plasticity and swelling reduction, enhanced workability and increased strength, it is unlikely to be a substitute for lime as the gain in strength is short-lived.

A study conducted by Andavan&Pagadala, [8] on the profligate soil properties examine the additional substances of lime and fly ash in soil are shown satisfactory result. The lime stand-alone has customarily been utilised in mud bearing cause a very strong soil. While, the used of fly powder and lime on the geotechnical qualities of mud fly fiery debris and earth lime blends was examined by conducting standard Proctor compaction tests, the tests were executing according to Indian Standard specifications. The analysis shows that the strengths of lime and fly ash stabilised soil after 7 and 28 days are greatly increased by increased density and compaction, but the optimum lime to fly ash ratio is influences in significant. As a conclusion, the decrease in strength is approximately proportional to the decreasing percentage of solids.

According to the study conducted by Fei et. al., [9], the enormous demand for soil stabilisation in cement intensifies the carbon footprint on the environment, which can be eased by replacing cement

with supplementary cementitious materials (SCMs). The study use sintered limestone ash (SLA) which is a waste from the steel industry. The main objective of this study is to investigate the feasibility of replacing cement for soil stabilisation. Laboratory testing such as laser particle sizer, scanning electron microscopy-energy dispersive spectroscopy (SEM- EDS), X-ray diffraction (XRD), thermogravimetry (TG), and X-ray fluorescence (XRF)for sample with the SLA was revealed to process a certain reactivity to hydrations. The mass fraction of cementitious materials like cement and SLA was regulated to 10 % of the total dry mass of solids to prepare the stabilized soils, and in another batch of samples the SLA was substitute the cement content of 0%, 5 %, 10%, 15 %, 20%, 50%, 80% and 100%. The UCS testing for all sample shows significant improvement in soil strength where the compactability and hydraulic conductivity performance of the stabilised soils were enhanced with increasing SLA replacement ratios.

According to the study conducted by Andavan&Pagadala, [10], the water properties in the soil are a common problem in soil stabilisation and cause the difficulties to design any structure on clay soil due to high shrinkage, low bearing limit, swelling qualities and high defencelessness in humidity. The stabilisation of this soil using additive which is lime are used to enhance the strength. Lime is locally accessible for the investigation and through this research method, the stabilised soil was tested using optimum moisture content, unconfined compression test, direct shear test, liquid limit and plastic limit, and moisture content with the introduction of fly ash as supplementary binder. The results show that the liquid limit has been increases by adding of fly ash by 20%, where plastic limit has been decreases by adding of fly ash up to 20%. It shows that lime fly ash stabilised soil after 7 and 28 days are greatly increased with the increased density and compaction, but the optimum lime to fly ash ratio is influences in significant.

In another study, James, [11] investigate the ability of sugarcane pressing mud (PM) as a secondary additive to lime content for expansive soil stabilisation. The soil properties like plasticity, shrink-swell behavior, unconfined compressive strength (UCS), mineralogical and microstructural characteristics have been investigated. In this study, the soil was stabilised using 7% lime and achieved the optimum strength. The lime was than substitute with different percentage of sugarcane pressing mud (PM) varied in ratio 0.25% to 2%. The result from the unconfined compressive strength test shows that the sample containing PM resulted in a substantial improvement in 7 days of curing period and a notable increase in lime-stabilized soil (LSS) strength at 28 day of curing period. The studies conclude that the application of PM, while being a substance of organic origin, does not induce any adverse changes to the soil properties as well as to the plasticity quality of the stabilised soil.

In another study conducted by Mokhtar et. al., [12], the laboratory experiment on dust shell as an admixture has been extensively used for the improvement of soft clay soils, in enhancing the shear strength and limiting the deformation behavior. The dust shell is an alternative cheaper admixture agent to partially replaced cement in soil stabilisation. The stabilised samples were prepared by mixing the kaolin with 5 % cement and various percentage of dust shell. The testing that been conducted include Atterberg limits, maximum dry density (MDD), optimum moisture content (OMC) and unconfined compressive strength (UCS). Result shows that the addition of dust shell slightly increases the maximum dry density and reducing optimum moisture content. In addition, the unconfined compressive strength of 5% cement-treated with dust shell samples increases with an increase of the amount of dust shell. This study indicates that cement-dust shell has a potential as an alternative soft soil stabilizer in soft soil stabilization with highlight the economic and environmental friendly material utilize.

Kuzhali& Krishnan, [13] use sea shell powder to improve the strength of black cotton soil. As the black cotton soil known as an expansive soil which is basically susceptible to volumetric changes with the changes in moisture, it is possible to use a binder to improve their strength. The result indicates

that there are a significant increased on the unconfined compressive strength of black cotton soil by adding sea shell powder as admixture. The study conclude that by adding sea shell as binder in black cotton soil, the unconfined compressive strength has been increased.

In another study, Liang & Wang [14] use Oyster Shell as a cementing material in remediated the problematic soil. The study aim to investigate the potential of pulverized oyster shell which is rich in calcium, when mixed with fly ash and soil. The cylindrical compacted soil and cubic lime specimens with different proportions of the shells and fly ash are prepared to test their strength. Soil, which is classified as clay with low plasticity (CL) in the USCS system, commercialized pulverized oyster shell, F-type fly ash, and lime are mixed in different weight percentages. Five sample groups prepared containing soil and lime specimens. The lime cubes are mix with 0.45 W/B ratio and the cylindrical soils are compacted under the standard Proctor compaction process with 20% moisture content. The results show that increment of shell quantity result to lower strength on both the soil and lime specimens. In a 56-day of curing, the compressive strength of the lime cubes containing fly ash increases evidently while those carrying the shell get little progress in strength. The soil specimens containing fly ash gradually gain strength as curing proceeds. It suggests that mixtures of the shell and fly ash do not process any Pozzolanic reaction nor help to raise the unconfined strength of the compacted soil through the curing.

3. Conclusion

Industrialization and urbanisation are the two main causes of the increasing contamination of soils and sediments. Contaminated soils and sediments have negative effects on the characteristics of the soil/sediment type itself, resulted to the mineralisation and accumulation of contaminant. Stabilization/Solidification (S/S) is a method that involves mixing of waste with binders to reduce the volume of contaminant in soil by any means of physical and chemical characteristics to convert waste in the environment that goes to landfill or others possibly channels.

The fast- growing world of industrialization today certainly emit a lot of contaminant that can disrupt the quality of soil. To ensure that these problems can be reduced and finally be solved, a systematic prevention method should be done by the government or any responsible authorities. It is shown by these studies that that S/S remediation methods using various type of binders has made an attempt to solve this long overdue problem. These studies found that by using recycle material or waste material such as bagasse ash, rice husk, sea-shell, and biochar able to improve the quality of soil treatment. Overall, it can be conclude that most of the additives used are able to help in improving the treatment of contaminated soil. Therefore, the functions and results obtained from the use of these additives are seen to be different depending on the objectives of the study conducted.This founding also means that the industry able to use sustainable and environmentally friendly material for remediation method.

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