Construction and Building Materials 116 (2016) 79–86

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Evaluating feasibility of modified drilling waste materials in flexible base course construction

Chang-Seon Shon [a,*], Cindy K. Estakhri [b], Dongoun Lee [c], Dichuan Zhang [a]

[a] Department of Civil Engineering, Nazarbayev University, 53, Kabanbay Batyr Ave., Astana, Kazakhstan
[b] Texas A&M Transportation Institute, Texas A&M University System, College Station, TX 77843-3135, United States
[c] Department of Architectural Engineering, Dongseo University, 47 Jurye-ro, Sasang-gu, Busan 617-716, South Korea

HIGHLIGHTS

- Modified drilling waste materials (MDWMs) were evaluated as base course materials.
- MDWMs did not show the same performance as typical flexible granular base aggregate.
- 3% cement treated MDWMs showed good performance as flexible base course materials.

ARTICLE INFO

Article history:
Received 11 June 2015
Received in revised form 9 April 2016
Accepted 26 April 2016
Available online 3 May 2016

Keywords:
Modified drilling waste materials
Base course materials
Stabilization/solidification

ABSTRACT

The study focuses on the evaluation of the engineering properties of modified drilling waste materials (MDWMs) as base course materials in roadway construction. This goal was accomplished by two main laboratory test evaluations of the MDWMs which are the basic material characterization and the performance evaluation of base course material. Material characterization results of the MDWMs indicate that they are relatively high pH, low plastic, and clay sand materials, mainly consisting of quartz and barite and belonging to Grade 4 category in Texas Department of Transportation (TxDOT) Item 247 Flexible Base Aggregate. The unconfined compressive strength (UCS), triaxial compressive strength, indirect tensile strength, moisture susceptibility, and seismic modulus test data show that the untreated MDWM is lower than many of these requirements and is not a granular base material when compared with the typical base course requirements identified in the Item 247. However, evaluation of the MDWMs with 3% cement treatment in the laboratory showed good performance without sacrificing their abilities as proper base course materials and satisfied the requirements of Class M base as per TxDOT Item 276. However, it may be necessary that the quality control of this material be monitored in order to achieve consistent moisture content and gradation. Moreover, further work to establish optimum stabilizer content and type would be recommended for this material.

1. Introduction

Drilling fluid is a preparation of water, clays, and chemicals circulated in oil-well drilling for lubricating and cooling the bit, flushing the rock cuttings to the surface, and plastering the side of the well to prevent cave-ins. Drilling fluids are typically classified into water-based mud, oil-based mud, and gaseous drilling fluid [1–3]. Theses drilling activities produce large amounts of drilling waste materials (DWMs) such as drilling mud and cuttings consisting of both liquid and solid phases. The management of these waste materials depends on the types of drilling fluids utilized. While water-based drilling wastes are simply disposed to open pit (mud pit), oil-contaminated wastes are typically disposed after subjecting them to a thermal treatment process. This treatment brings the oil content under "Special Waste" classification threshold and produces a more easily handled dry product [4].

Other techniques are used to solidify and stabilize the DWMs. Cementitious materials such as cement, lime, and fly ash are typically used in the stabilization and solidification process of DWMs. Cement-treated stabilization and solidification improve the physical, chemical, and mechanical properties of DWMs by binding their contaminants such as oil and metals in a structure formed by the cementitious materials [5–7]. As a result, either thermally-treated or cement-treated DWMs can be transformed to a soil-like, compactable mixture and may potentially be used

* Corresponding author.
E-mail addresses: chang.shon@nu.edu.kz (C.-S. Shon), c-estakhri@tamu.edu (C.K. Estakhri), ldu21@gdsu.dongseo.ac.kr (D. Lee), dichuan.zhang@nu.edu.kz (D. Zhang).

http://dx.doi.org/10.1016/j.conbuildmat.2016.04.100
0950-0618/

as a construction material in roadway construction. This material is called a modified drilling waste material (MDWM).

In recent years, several researchers have investigated the utilization of oil-based drilling wastes as construction materials. Page et al. [4] suggested three potential options for reuse of drilling waste in construction applications on the basis of a summary of previous research: (i) use in cement manufacture; (ii) use in roadway construction; and (iii) use in brick and block manufacture. Bernardo et al. [8] investigated the feasibility of oil well-derived drilling wastes as components of the kiln feed during the process of the Portland cement manufacture. It was found that the drilling wastes were partially able to replace limestone and clay in the cement clinker manufacture by up to 45% without degradation in performance of the hydraulic binders.

Offshore drilling waste was also used in hot mix asphalt (HMA) concretes as aggregate replacement [9]. It has been found that as much as 20% drilling waste could be used as aggregate replacement in HMA concrete without sacrificing any of its properties such as Marshall stability, flow, permeability, and resilient modulus. Tuncan et al. [10] stabilized petroleum-contaminated drilling waste (PDW) with 20% lime, 10% fly ash, and 5% cement and evaluated them as road subbase materials. They found that significant increases in the unconfined compressive strength, California bearing ratio, freeze-thaw resistance, and pH, depending on waste material's grain size, stabilizer type, and inherent composition property of PDW.

Chen et al. [11] used thermally treated oil-base mud cuttings from drilling operations to manufacture permeable clay bricks. Furthermore, they have used these materials as a partial cement substitute in concrete. They reported that both brick and concrete made of drilling wastes successfully met Taiwan National Standard specification requirements in terms of permeability and strength. El-Mahllawy and Osman [12] have successfully used thermally-treated oil based mud waste to cast clay masonry units for load and non-load bearing walls construction which met the acceptable limits of an Egyptian Standard.

It is estimated that approximately 29,097,984 cubic yards of solid drilling waste are generated annually in the United States [13]. The drilling waste management to minimize the environmental impact of drilling operations is one of the most important challenges in the petroleum industry. As previously stated, some research to further exploit the utilization of oil-based drilling wastes as construction materials has been conducted. However, little data are available on the application of these materials in roadway construction. Furthermore, because of an increasing scarcity of some sources of conventional aggregate and the high cost of transporting aggregate to the construction site, the interest in alternative reliable cost-effective materials that are more available locally or in-situ for both flexible and rigid road-bases is significantly increasing in Texas.

2. Research objective and experimental scope

The objective of this research was to evaluate the engineering properties of modified drilling waste materials (MDWMs). As illustrated in Fig. 1, this goal was accomplished by laboratory test evaluations of MDWMs which are further categorized into two experimental series: Series I-Determination of the basic material characterization of the MDWMs and Series II-Evaluation of the MDWMs according to Texas Department of Transportation (TxDOT) Specification Item 247-Evaluation of Base Course Materials.

Series I focuses on the method for designing a road base material using treated petroleum-based drilling waste, sampling of MDWMs, and characterization of chemical, physical, mineralogical, and geotechnical aspects of MDWMs.

In order to assess the performance characteristics of this MDWMs as road base course materials, the testing protocol in Series II includes the determination of optimum moisture content, unconfined compressive and indirect tensile strengths of the fabricated specimens, evaluation of the moisture susceptibility using the capillary suction test and triaxial compression test, and seismic properties as per TxDOT guideline for base course sample evaluation.

3. Production of modified drilling waste materials

As previously stated in Introduction session, a common method for processing drilling wastes is through solidification and/or stabilization by treating the waste with cementitious materials and inert materials (aggregates). Figs. 2 and 3 illustrate an overview of the steps to produce modified drilling waste materials (MDWMs). The first step is to separate water from drilling fluid waste received from the oilfield site in the form of either tank liquids or truck solids. Because the water-removed solids are still coated with contaminants, the solids must be further treated with centrifuges for further removal of more of the contaminant.

The second step is a stabilization and solidification process, wherein, treated drilling waste is combined with aggregate and a binder. The effort to stabilize the waste with cement is to reduce free moisture and minimize the solubility and mobility of the pollutant inside the waste. The solidification is aimed at increasing the bearing strength, decreasing the surface area of the waste, and converting the suspension or detached component inside wastes into a monolithic solid product of high structural integrity [10,14]. To produce the MDWMs, an approximate ratio of treated drilling fluid waste to aggregate (sand) of 3 to 1 was used. In addition, 12% cement kiln dust of the total dry solid materials was added to the mixture.

The final step is to cure the MDWMs to obtain additional strength for use as road base course materials in the form of stockpiles. The coarser particles present in the excavated MDWMs are meant to satisfy the aggregate capacity in the base course. The unhydrated cement particles would potentially stabilize and bind the mix together by means of the residual cement hydration intrinsic to the stockpiled material when water is applied during base course construction. It should be noted that the materials on the stockpile should be stored properly to avoid rainfalls because the properties of stockpiled materials could be different if some rain falls on the stockpiles.

4. Determination of basic material characterization of the MDWMs

4.1. Material sampling and particle size analysis

As previously noted, the aim of this project is to determine the acceptability of modified drilling waste materials (MDWMs) for use in road base course application. In order to obtain accurate test results for this experimental program, 2 sets of MDWMs (designated as MDWM-A and MDWM-B) were obtained from the plant stockpile. During stockpile sampling of MDWMs, the excavator bucket broke through the hardened material and generated both fine and coarse particles. The sieve analysis of the excavated MDWMs was performed in accordance with the TxDOT test method Tex-110-E "Particle Size Analysis of Soils." Before sieving, MDWM agglomerates larger than 44.5 mm were reduced in size, as permitted by the Tex-101-E test method "Preparing Soil and Flexible Base Materials for Testing" in order to achieve a 100% utilization of the material. A suitable size of the MDWMs was obtained by quartering and splitting. The sieve analysis was performed on the fully dried MDWMs.

Texas Department of Transportation (TxDOT) Item 247 guideline specifies four different grades of aggregates that can be used in flexible base construction. Particle size distribution analyses of MDWMs are given in Fig. 4. While the MDWM-B material conforms to Grade 1, the MDWM-A material does not meet the gradation requirements for Grade 1 through 3 specified by TxDOT Item 247 regardless of using wet or dry sieving. The MDWM-A material contains more fines than permitted for Grades 1 through 3 as