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In-situ and laboratory investigation of modified drilling waste materials applied on base-course construction

Chang-Seon Shon [a,*], Cindy K. Estakhri [b,1]

[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, United States*

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Abstract

This study focuses on in-situ and laboratory evaluation of modified drilling waste materials (MDWMs) applied on base course construction. Cement treated drilling waste materials have been used on a limited basis for full-depth base repair on Texas Department of Transportation (TxDOT) low volume roads. A road inspection was made of full-scale county roads that were constructed with the MDWMs. Field test results measured by the falling weight deflectomer (FWD) showed reasonable in-situ strengths. The MDWM section had stiffness values similar to those typically observed for newly constructed flexible bases. The old, in-service flexible base adjacent to the MDWM section exhibited values half those of the MDWMs. Cores removed from the field also had significantly higher strength values than the lab-molded samples. Moreover, the other non-TxDOT low volume county roads using MDWMs exhibited good field performance. From this observation, it is concluded that this material clearly has some unique engineering properties which has the ability to gain strength with time though weak initially and there is the potential applicability used in the low volume roadway.

Keywords: Modified drilling waste materials; Base-course construction; Low volume road; Base stabilization; In-situ investigation

1. Introduction

Flexible pavement structures must be capable of withstanding the loads imposed by traffic irrespective of weather conditions. The body of a pavement structure is constructed from different layers of different thicknesses, depending on the anticipated traffic load. The function of a base course in the pavement structure is to provide a uniform foundation of high stability for both upper- and sub-pavement structures [1]. The base course absorbs the forces from traffic and provides for uniform distribution of these forces onto the sub-base. It also ensures quick and effective protection of the sub-base against water to maintain its load-bearing capacity. Furthermore, the base course offers excellent bearing capacity and is capable of withstanding a broad range of different climatic conditions. The required bearing capacity is achieved using a mixture of gravel, chippings and crushed sand that needs to be compacted to the required density [2,3].

The quality of a base course layer depends largely on proper material selection and the quality of the construction techniques used. For example, pavement distress such as alligator cracking can be minimized if the base layer is constructed properly using appropriate aggregates that maintain their integrity throughout the life of the pavement. A base course mix might be well designed and well produced, but if it is placed in the road in an improper way, the base layer performance will be poor. Therefore,

* Corresponding author.
E-mail addresses: chang.shon@nu.edu.kz (C.-S. Shon), c-estakhri@tamu.edu (C.K. Estakhri).
[1] Fax: +1 (979) 845 0278.
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next to mix design, construction, homogeneity, and degree of compaction must be considered the main quality parameters of a laid base mixture. A well designed and well produced mixture performs better, has better durability, and has better mechanical properties when it is well compacted.

In recent years, several researchers have investigated the utilization of oil- or water based drilling waste materials including drilling mud and cuttings as construction materials after a thermal treatment process or solidification and stabilization process using cementitious materials [4,5,6,7,8,9,10,11]. For example, Wasiuddin et al. [12] have used off shore drilling waste in hot mix asphalt concrete (HMA) as aggregate replacement. They found that as much as 20% drilling waste could be used as aggregate replacement in HMA concrete without sacrificing its stability, flow, permeability, and resilient modulus. Onwukwe and Nwakaudu [13] and Bernardo et al. [14] has reported that used drilling mud can be used to make cement.

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 aggregates for both flexible and rigid road-bases is significantly increasing in in-situ. This paper presents the post-construction assessment for road base-course sections constructed with modified drilling waste materials (MDWMs). The performance of MDWMs has been assessed in terms of in-service performance and field cored samples using non-destructive test methods. Ground penetration radar (GPR), falling weight deflectometer (FWD), dynamic cone penetration (DCP), and rutting test were used for the in-service performance evaluation. For cored samples, moisture content, dry and wet density, stiffness and seismic modulus, unconfined compressive strength, and modulus of rupture were evaluated.

2. Test roadway section description

An approximately 700 m test section on Farm to Market Road 2674 (FM 2674) in Wharton County, Texas was tested as outlined in Fig. 1. The modified drilling waste materials (MDWMs) and sea-shell base materials were used from station 113+00 to 116+35 while conventional gravel base-course materials (PE3 materials) were used from station 116+35 to 120+50. This road was constructed at November 1, 1960, but the detailed information such as water to cement ratio for base course and subgrade is not available.

Fig. 2 also illustrates the typical cross section of existing pavement structure (station from 113+00 to 116+35) which consists of 2.54 cm asphalt layer, 15.24 cm base, and black clay subgrade. Two different materials were used in the construction of road base. The base-courses were constructed with the combination of the half of cement-stabilized sea shell material and the half of MDWM. Because this road had been constructed as a test road, the various materials such as sea shell and or MDWMs had been evaluated as base course materials. In 1960s, the utilization of sea shell materials as base course materials was common in Houston area, Texas.

3. Research scope and in-situ and laboratory tests

The objective of this research was to evaluate the performance of MDWMs applied on base course construction. As illustrated in Fig. 3, this goal was accomplished by in-service performance and laboratory test evaluations of field cored MDWM samples. GPR, FWD, DCP, and rutting test were used for the in-service performance evaluation. For cored samples, moisture content, dry and wet density, stiffness and seismic modulus, unconfined compressive strength, and modulus of rupture were evaluated in laboratory. Each test has been conducted with three specimens.

3.1. In-situ evaluation method

GPR was used to assess base layer thickness and layer interface condition. Voids and water trapped in and between underlying pavement layer can be detected using image analysis and dielectric constant (DC) on the basis of an air-coupled or ground coupled system vehicle [15].

The deflection testing using FWD was used to evaluate the structural capacity for layer stiffness. The FWD applies dynamic loads to the pavement surface, similar in magnitude and duration to that of a single heavy moving wheel load. The response of the pavement is measured in terms of vertical deflection. The data generated from FWD are combined with layer thickness and, in turn, modulus calculation through back calculation is used to evaluate pavement layers and underlying subgrade.

The DCP test was also conducted to measure the in-situ strength of base and subgrade materials in terms of penetration resistance in mm/blow. The DCP testing is commonly used to estimate the elastic modulus of each layer because it is fast and easy. The 8 kg weight is raised to a height of 57.5 cm and then dropped, driving the cone into the material layer being tested. After measuring the penetration depth per drop (each blow), the DCP penetration rate (PR) in millimeters per blow is computed. The derived PR is correlated to the California bearing ratio (CBR) values and subsequently used to compute elastic modulus of the material.

Rutting data which present surface depression in the wheel path for road test section were collected. They were measured manually.

3.2. Laboratory assessment method of field cored samples

The coring of field samples was conducted to determine the thickness of all pavement layers and strength. After trenching, slab samples were collected instead of coring in the field. The slab sample was evaluated in terms of moisture content, dry and wet density, stiffness and seismic property, unconfined compressive strength, and modulus of rupture.

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