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The Effect of Soil Improvements under Road Pavement along Diyala Governorate Highways

A Thesis Submitted to the Council of the College of Engineering / University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

((هُوَ ٱلَّذِي جَعَلَ لَكُمُ ٱلۡأَرۡضَ ذَلُولٗا فَٱمۡشُواْ فِي مَنَاكِبِهَا وَكُلُواْ مِن رِّزۡقِهِۦۖ وَإِلَيۡهِ ٱلنُّشُورُ))

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We certify this thesis entitled "**The Effect of Soil Improvements under Road Pavement along Diyala Governorate Highways"** was prepared by "**Omer Ahmed Abd-Allah**" was made under our supervision at the University of Diyala in partial fulfillment of the requirements for the degree of master of science in civil engineering.

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We certify that we have read the thesis entitled (**The Effect of Soil Improvements under Road Pavement along Diyala Governorate Highways**). We have examined the student (**Omer Ahmed Abd-Allah**) in its content and what is related to it, and in our opinion, it is adequate as a thesis for the degree of Master of Science in Civil Engineering.

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Dedication

To………

My father and my mother, who are both my heart and soul

My brothers and sisters, whose vision is the source of my happiness

To all my relatives that I am honored to have

To all of my friends whom I had the honor to know

To all my teachers whom I describe, who taught me a letter that I made a slave to

To every person who calls for success for me and wishes me well

I dedicate this humble work.

OMER AHMED

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"In the Name of God Most Gracious, Most Merciful"

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OMER AHMED

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ABSTRACT

Pavement failures correlated to subgrade soils defects are quite common in local highways. This may represent the major cause of excessive maintenance work if not the reconstruction process required to keep these highways serviceable. This could be attributed to many reasons, the most important of which are the types of soils and their characteristics in addition to the presence of a high level of ground-water. Accordingly; it was deemed reasonable to investigate the subsurface soils in the vicinity of Baquba City, which is taken as a case study, to come up with the most applicable improvement procedures through the application of several additives and scale their impact on the natural soils and consequently on the highway pavement performance.

Five additives were selected for the stabilization trials each with different percentages, these additives are; 3%,5%,7% and 9% quicklime,5%,10%,15% and 20% class F fly ash activated by 5% Portland cement,10%,15%,20% and 25% rock powder,5%,10% and 15% crushed waste concrete, and 2%,4%,6% and 8% crumb rubber of tires. All the percentages are by dry weight of soil.

The test program in this study included the UCS and un-soaked CBR tests which were conducted on each one of the controlled types of soil samples with the addition of about four different percentages of each of the five additives that may require some 60 UCS tests and 60 un-soaked CBR tests. The test results revealed that the optimum percentages of each stabilizer, in descending order of the additives preferability, were (25%) rock powder, (15%) crushed waste concrete, (15%) class F fly ash activated by cement, (9%) quicklime, and (4%) crumb rubber of tires. The increment in Young's modulus was calculated for each soil accordingly from stress-strain curves from the UCS test for the three soils using the whole used five additives' percentages. The best stabilizer according to the UCS test and unsoaked CBR test is the rock powder which raised the UCS by 904% for soil A and it raised unsoaked CBR by 570% for soil A too. Both of those increments were at 25% rock powder.

These optimum additive percentages admixtures choose to subject to the soaked CBR test for the three controlled soil types, hence conducting 18 soaked CBR tests which reveal a different priority in their results. The optimum enhancement to the natural soil is in this order; for the weakest soil type A, the optimum enhancement achieves by the addition of 15% of fly ash activated by cement, which increases the original CBR_S about eight times from 3.8% to 31%. For soil type B, the optimum additive is 25% of RP which increases the CBR_S a little shy five times from 3.95% of the natural soil to 19%. For soil type C, it finds that the optimum addition is 15% of CWC that increases the natural CBR_S value about three times from 4% to 11.5%.

Finally; the CBR structural design method for flexible pavement was consulted to scale the impact of the previously mentioned enhancements on local soils surrounding Baquba City. The results of this design method showed that; the stabilization to type A soil with 9% of quicklime will reduce the required pavement by 67%, from 54cm to 18cm, while the addition of 15% crushed waste concrete to soil type B will reduce the required pavement thickness by 45% of the original thickness, from 54cm to 24cm, while the addition of the same percentage as in type C which is 15% of crushed waste concrete will reduce the pavement thickness by 40% from 53cm to 32cm. Thus; the addition of the determinant additives to the local soils as distributed geographically is very well justified.

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LIST OF ABBREVIATIONS

Abbreviation	Term
AASHTO	The American Association of State Highway and Transportation Officials
ASTMD	American Standard of Testing Measurements
C-A-H	Calcium-Aluminate-Hydrate
C-A-S-H	Calcium-Aluminum-Silicate-Hydrate
CBR	California Bearing Ratio
CBR_S	Soaked California Bearing Ratio
CFFA	Class F Fly Ash
CL	Clay with Low Plasticity
CRT	Crumb Rubber of Tires
C-S-H	Calcium-Silicate-Hydrate
Cu	Undrained Shear Strength
CWC	Crushed Waste Concrete
MDD	Maximum Dry Density
$MDD_{modified}$	Modified Maximum Dry Density
M_{RS}	Resilient Modulus
NCCLR	National Center for Construction Laboratories and Research
OMC	Optimum Moisture Content
$OMC_{modified}$	Modified Optimum Moisture Content
PC	Portland Cement
QL	Quicklime
RP	Rock Powder
UCS	Unconfined Compression Strength
USCS	Unified Soil Classification System

Chapter One

Introduction

1.1 General

Road projects represent a criterion for the progress of countries due to the great role of these projects in serving the community in terms of economic and service aspects. In the past two decades, the need to construct strategic roads to keep pace with the rapid urban development in our cities has increased in order to improve the traffic situation, especially after the increase in traffic momentum as a result of the entry of large numbers of modern vehicles of different sizes and the increased design requirements for these roads. There was a need to improve the reality of the already established roads that were damaged as a result of neglect and lack of regular maintenance due to the financial and security conditions that the country is going through. It was directed to find economic solutions to address the reality of these roads. After on-site inspection by the committee assigned by the College of Engineering with this study of the affected areas. An action plan has been developed to study this problem and propose a number of treatments. It was noted that most of the road problems that were mentioned usually appear near the inspection checkpoints and entrances to cities of heavy machinery and trucks transporting heavy construction materials parked for the purpose of inspection, some of which have been there for more than 48 hours, as the loads of these trucks cause problems of rattan, cracks and erosion of the roads in those places in particular.

Roads are the most influential factor that consumes a large part of the annual infrastructure maintenance budget in most of our cities due to the cost of its materials, and most of the road problems are related to the failure of the subgrade soil, which affects all paving layers and thus work on its entire maintenance (Adlinge & Gupta, 2013).

Road rehabilitation has significant environmental and social benefits as it plays an important role in our daily lives, and provides safe and comfortable transportation, which is one of the main aspects of our lives. Good management and adequate funding must be provided to preserve it and prevent its potential damage as a result of surface deformation such as the appearance of grooves and cracks as a result of exposure to unsuitable environmental conditions or the presence of problems in the subsoil, which leads to its failure and unsuitability for the loads designed for it. The problems of the subsoil directly affect the performance of the roads if they are not dealt with properly during the design phase, which leads to impeding the movement of vehicles due to obvious changes in their carrying capacity due to the impact of climatic changes that may affect the paving layers and the emergence of some serious structural deformations (Wada, 2016).

Soil depends on the origin and type of soil minerals, location, stress history, and climate. These factors have a significant impact on the design, construction and management of road surfaces. In addition, the improvement will have a major role in increasing the bearing capacity of the vehicles and resisting the difficult climatic conditions in our country. Knowing the properties of the soil has a key role in understanding the negative behavior of the behavior of these soils (Mwaipungu & Ahmed, 2017).

The tremendous development that took place in our local cities and urban areas required a huge expansion in highways and road networks whose construction, maintenance and rehabilitation encouraged the use of soil stabilization technology for these roads with various chemical and physical materials, and these methods have proven their feasibility to give permanent treatments in the field of road construction (Daud et al., 2019).

1.2 Define the problem

The main highways in Diyala Governorate suffer from subsidence and the appearance of bumps and sagging due to the increase in traffic as a result of the increase in the number of vehicles and the passage of heavy vehicles, which leads to the occurrence of road problems such as shoveling, cracks and rattan. Usually, these defects occur either due to the failure of the road itself or the failure of the subgrade soil or the so-called subgrade soil. In the first case, maintenance is easily done by scraping back sections of the damaged asphalt and paving them again, but in the second case, the problem is much deeper and requires more than correcting the overhead sections of the pavement.

In many cases, the asphalt layer is removed and then scraped and replaced with the damaged soil and then the road is built again, and this is a very expensive process, especially if the road is long. Therefore, there was a need to find practical and economical ways to address this problem. The effect of the presence of soil under the roads requires procedures for its improvement, and the mechanism and technique of improvement differ from one site to another depending on the type of soil and climatic changes such as humidity and temperature.

As for the highways connecting the city of Baquba with villages and kasbahs, road defects are very common and noticeable, especially along the low-speed paths to city entrances and checkpoints. Most of these defects are caused by the failure of the subsoil and require a lot of resources to maintain. Accordingly, the improvement of the subsoil under the roads increases its bearing capacity to the load of passing vehicles and prevents the occurrence of cracks and erosion in them. Plate (1.1) shows some types of construction problems in some highway areas in Diyala Governorate.

Plate (1.1) Examples of failures of pavements along with Diyala governorates that this study tries to solve geotechnically

Although soil investigations have been conducted for each highway, there is no record of potential reinforcement actions for any area within Baquba city or its suburbs.

This study deals with the definition of the engineering characteristics of ten selected areas for the most affected areas in their main roads. And studying the effect of some additives on improving their engineering properties, reducing their compressibility, and rehabilitating them in proportion to the continuous civil development with the increase in the number of vehicles and the increase in their ability to carry trucks and heavy vehicles. This study focuses on the effect of strengthening the subsoil of the highways linking Diyala Governorate, especially those surrounding the capital, Baquba. Soil samples were collected from ten selected points along the five main highways linking Baquba city with the surrounding areas. The distances of these sample sites from the city center range from 5 to 10 kilometers. Plate (1.2) shows the locations of the lower soil layers of the Diyala Expressway.

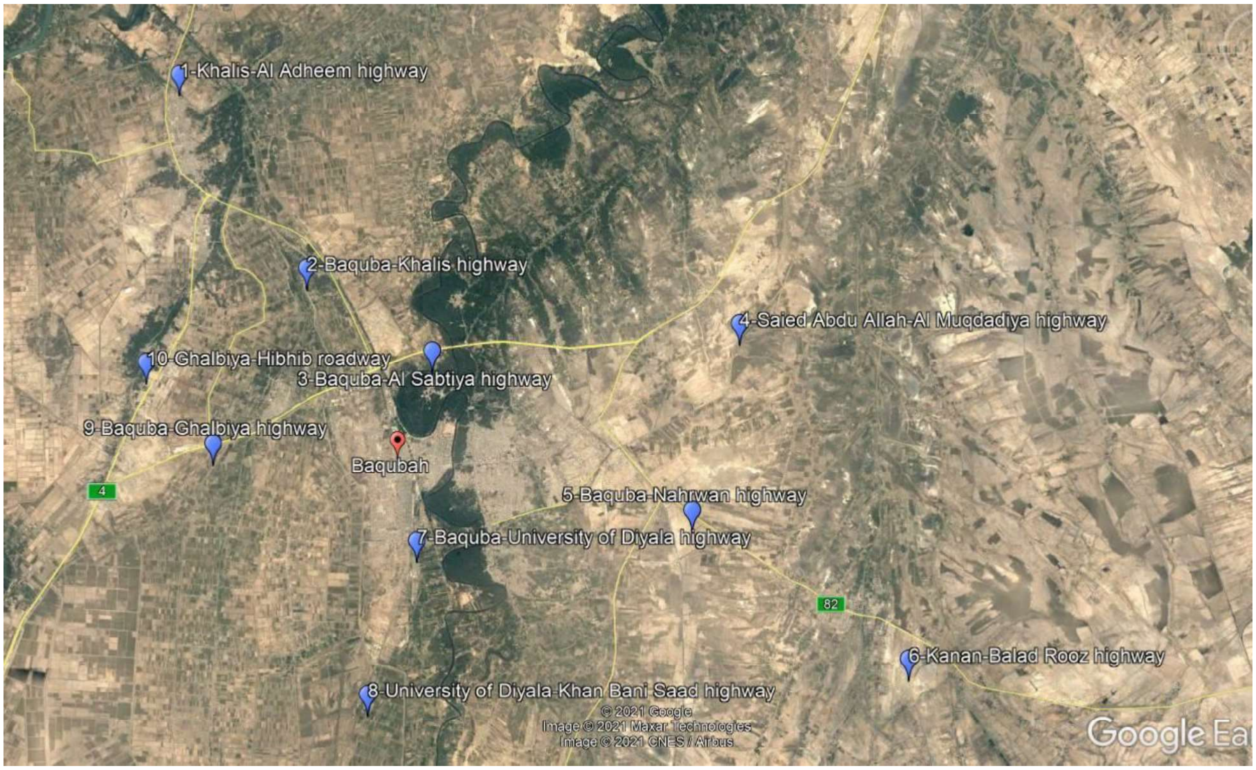

Plate (1.2) Sampling along Baquba Highways

1.3 Objectives of The Study

The presence of weak, slightly bulging soils is common in most of the central and southern Iraqi regions as the loose soils which represent an estimated 35% of the total clay lands in Iraq. This soil is sensitive to water and has great elasticity, compressibility and high plasticity. It may expand and swell at certain times. These properties make this soil harmful to many types of buildings to be built on, including lightweight buildings and roads. Therefore, it is necessary to provide the latest solutions to the problems of this soil and the possible means for their implementation. One of the most appropriate methods is to stabilize the soil under the foundations of various buildings or sidewalks with physical and chemical additives and to measure the suitability of each of its different types, including the additives used in this research. The results of this study, indicate the most applicable additives that enhance local soft soil properties, are expected to be a powerful tool in the hands of highway pavement designers, through which pavements are more durable, highly efficient, less expensive and have a longer life. can be built.

1.4 Thesis Layout

The layout that this thesis generally consisted of five chapters organized as follows:

Chapter One: Which presents a brief introduction about the basis of this thesis, the problem intended to be solved, the significance of the study, the purpose, and the structure.

Chapter Two: Presents information background about the thesis from close previous studies in the literature and introduced them as review.

Chapter Three: Explains the experimental work conducted in the soil-mechanic laboratory and introduces the physical and chemical properties of the natural tested soils and the admixtures.

Chapter Four: Presents the results of the stabilization worked tests in this study and the analyses and discussions concerning the test results.

Chapter Five: This chapter shows the conclusions that were extracted from the results presented and discussed in chapter four and introduces the necessary recommendations.