

ASSESSMENT OF PROPOSED ASPHALT CONCRETE MIX USING IMPROVED AGGREGATES, SOIL STABILIZATION AND QUALITY CONTROL IN IMPROVING FATIGUE LIFE AND RESISTANCE TO PERMANENT DEFORMATION IN KUWAITI ROADS

Khaled Sh Alajmi

Construction Training Institute -The Public Authority for Applied Education & Training
(PAAET)

Jasem Y Alkandari

Construction Training Institute -The Public Authority for Applied Education & Training
(PAAET)

ABSTRACT

This study aimed at investigating the influence of proposed asphalt concrete mix using improved aggregates, soil stabilization and quality control in improving fatigue life and resistance to permanent deformation in Kuwaiti roads. The used methodology included testing the stability, compatibility, water immersion and fatigue life of the aggregates before and after coating. The methodology included also reviewing the related literature in order to find the effect of the quality control programs on enhancing the performance of the roads. The results of this study showed that the stability and voids of the cement treated mixes have increased with the degree of cement coating. The higher void content indicated to reduction in compatibility of the mix and this result in low stabilities. The results showed also that increasing the blows did not effect on the asphalt content of different concrete mixes. Any increase or decrease in compressive strength affect directly with an inverse relationship of the fatigue life of the concrete mixes of the pavement.

Keyword head: Concrete Mix, Improved Aggregates, Soil Stabilization, Quality Control, Kuwaiti Roads.

Cite this Article: Khaled Sh Alajmi and Jasem Y Alkandari, Assessment of Proposed Asphalt Concrete Mix Using Improved Aggregates, Soil Stabilization and Quality Control in Improving Fatigue Life and Resistance to Permanent Deformation in Kuwaiti Roads. International Journal of Civil Engineering and Technology, 10(3), 2019, pp. 2123-2132

<http://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=3>

1. INTRODUCTION

Engineers are continuously working on improving the asphalt pavements performance. Modifications are taken to improve pavement performance. In Kuwait, asphalt mixture is widely used in the construction of roads where the majority of roads are paved with asphalt mixture as in most of the countries in the world [1, 2]. Asphalt mixture is mainly used because of its good service pavement and performance [3, 4]. Asphalt mixture is consisted of asphalt binder, filler and aggregate [5]. Mainly, the aggregate is involved in the asphalt mixture skeleton formation. Asphalt and Filler are the key asphalt mastic components that cements and fills the skeleton of the asphalt mixture [6, 7]. The aggregate accounts for more than 90% of the asphalt mixture by weight. Therefore, the construction of asphalt pavement consumes great amounts of natural rocks. Many strategies have been proposed in order to reduce the supply pressure of high-quality natural aggregate. The typical method is using low-quality aggregate or some solid wastes as substitute materials [8].

This study will proposes an asphalt concrete mix using improved aggregates, soil stabilization and quality control in a contribution to improve fatigue life and resistance to permanent deformation in Kuwaiti roads.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Effect of improved aggregates on Concrete Mix design

Recent researches were done to improve the aggregates in the concrete mix design by a process called cement coated process for upgrading marginal aggregates. The main principle for this process is to create a rough textured surface on the particles of the aggregates. A Portland cement and water paste covers the surface of the articles with a cement film that cure completely. The coated material can be used in bituminous mixes of concrete. This raises the adhesion between the aggregate particles and the asphalt binder, increase the internal friction and increase the shear strength of the mix and the load bearing capacity of the mix of aggregate binder so that it can provides longer lasting pavement and this can increase the fatigue life of the of the mix and decrease the deformation occurred in it. To check the concept of cement coating process, see Figure 1.

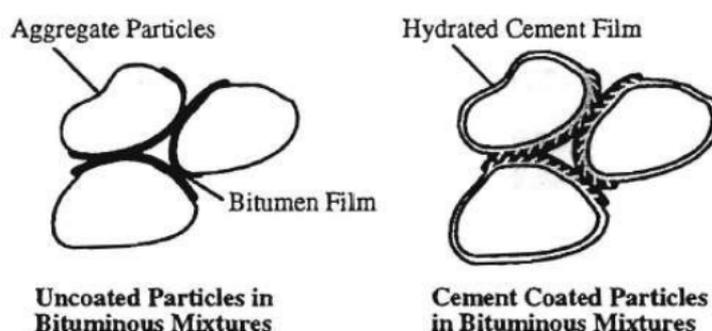


Figure 1. Cement Coating Process [9]

Experiments plan was done to test four types of aggregates. Aggregates size range from fine sand to one inch rock. There were separately coated with cement, cured and blended to produce the required mix in each case. Laboratory and experiments were done to coat the previous aggregates with a Portland cement used in HMAC (Hot Mix Asphalt concrete). To evaluate the resistance of the mix to deformation, Researches tested the mechanical properties of the coated and uncoated aggregates using many tests as Hveem and Marshall

Stability and resilient modulus as a function of tension, moisture, permanent deformation, Temperature and creep. The results proved that asphalt mixture can be performed well with cement coated aggregates using the standard TxDOT (Texas Department of Transportation) method.

In both of laboratories and field, the coated aggregated with a cement paste according to the guidelines will exhibit a uniform rough and textured surface for the aggregate particles and will not form temporary or permanent deformation which might effect on the aggregate negatively on the gradation of the Hot mixed asphalt concrete.

But microscopy tests revealed about 55-70 % of the mixture ware off in the mixing process so if the aggregates are unsuitable to be used in pavement surface course because of the poor surface friction, the cement coated process cannot be used effectively in to upgrade the aggregate in the field.

2.2. Effect of Soil stabilization and quality control on Concrete Mix design

There are many methods for soil stabilization to improve the performance and properties of soil and this can affect directly on the fatigue life of the soil that will be used in the roads in addition to the resistance of deformation becomes high. Soil stabilization can be performed by cement and lime stabilizations. Also Quality control has a very important role to ensure that the final product will be suitable for use. It must insure that the specifications and plans were performed well on the final product before using. We will discuss the cement and lime stabilization in the next content.

2.2.1. Cement stabilization of soil

There are many important factors for quality control standpoint in cement stabilization as Pulverization, cement content, moisture content, and time sequence of operations, curing, compaction and uniformity of mixing.

2.2.1.1. Pulverization

Pulverization will not be a problem in cement unless the clayey or salty soil is being stabilized. Sieve analysis is done during this process with the No. 4 sieve used as a control. The percent of Pulverization can be calculated. Also the control of the moisture content is important to achieve the required level of pulverization.

2.2.1.2. Cement Content

The optimum level of moisture content is very important because it is used as an initial guide when construction begins. The maximum density and optimum moisture content can be done for field control purposes. Now, nuclear methods can be done to determine the moisture content.

2.2.1.3. Uniformity of mixing

This can be achieved by visual inspection through the treated depth so quality control and assurance is very important here. Uniformity should be checked through the width of the payment and the treated depth. A satisfactory mix will exhibit a uniform color through it.

2.2.1.4. Compaction

It can be done by a number of equipment. Equipment used for compaction is the same if no cement were present in the soil.

2.2.1.5. *Curing*

It should be done on large areas to cover all the soil surfaces. The surface of the soil cement should be free of dry loose material and in a moist condition. It is important that the soil-cement mixture be kept continuously moist until the membrane is applied. The recommended application rate is 0.15 to 0.30 gallons per square yard.

2.2.2. *Lime stabilization of soil*

The same factors will be in the lime stabilization as pulverization, compaction, lime content and curing.

2.2.2.1. *Pulverization:*

Before applying the lime, the soil is pulverized and scarified to ensure the adequacy of this phase in the construction process. Sieve analysis is performed. Depth of the pulverization is important because it relates to the depth of the lime treatment.

2.2.2.2. *Lime content:*

When lime is applied to the pulverized soil, the rate at which it is being spread can be determined by placing a canvas of known area on the ground and, after the lime has been spread, weighing the lime on the canvas. Charts can be made available to field personnel to determine if this rate of application is satisfactory for the lime content specified.

To accurately determine if this rate of application is satisfactory for the lime content specified. To accurately determine the quantity of lime slurry required to provide the desired amount of lime solids, it is necessary to know the quantity of lime slurry required to provide the desired amount of lime solids, it is necessary to know the slurry composition. This can be done by checking the specific gravity of the slurry, either by a hydrometer or volumetric-weight procedure.

2.2.2.1. *Uniformity of Mixing:*

The main idea is to achieve uniform lime content through the depth of the treated soil. This is one of the most difficult factors to be controlled in the field. It was said that the mixed soil and lime has more or less the same outward appearance as mixed soil without the lime.

2.2.2.2. *Compaction:*

Proper control is significant for the moisture density. Conventional methods as rubber balloon and sand cone are used. Nuclear methods can be done to determine the compacted soil density.

2.2.2.3. *Curing:*

Curing is essential to assure that the soil lime mixture will achieve the final properties desired. Curing is accomplished by one of two methods: moist curing, involving a light sprinkling of water and rolling; or membrane curing, which involves sealing the compacted layer with a bituminous seal coat.

2.2.2.4. *Fatigue Test:*

The Fatigue test is performed on the soil specimen similar to the specimen prepared in unconfined compression test and the samples were tested for 7days with curing. The Fatigue test equipment can apply the repeated loads at a frequency 0 to 12 Hz is used in the present investigation. The equipment is procured from SPANTROICS, Bangalore. The cylindrical

sample was tested on the loading frame and the deflection sensitive transducers are set to read the specimen deformation. Results will be discussed later.

Hveem stability tests showed an increased resistance of permanent deformation with the mixtures of cement coated aggregates. For Marshall test, there were not a big difference between the two cases of the aggregates in tensile strength.

Cement coating improved the moisture resistance with 60%. Creep tests on asphalt concrete specimens indicated that cement coated aggregates have a higher shear strength then provides a better resistance to pavement rutting than ordinary uncoated aggregates.

3. RESULTS AND DISCUSSION

From the results of the test of Marshall in Table 1, we see that the untreated mix has the lowest stability although it has high density. Addition of 1% of aggregate weight of hydrated lime did not change the density or voids content but it increases the density by 9%. This increase because of the fineness of the hydrated lime compared to the limestone dust. Rows from 3 to 5 in Table 1 shows that the stability and voids of the cement treated mixes have increased with the degree of cement coating. Specimens with increasing cement coating are higher in voids and stability with different percentages as shown in Table1.

Table 1. Results of Marshal Stability tests

Treatment type and degree	Optimum asphalt (%)	Marshal stability ratio (%)	Bulk density (g/cm ³)	Void content (%)
Untreated	4.10	98	2.40	3.30
Hydrated lime, 1% cement	4.20	105	2.42	3.30
Light	4.40	108	2.37	3.80
Medium	4.45	111	2.35	4.00
Heavy	4.40	124	2.35	4.50
Light	4.40	94	2.33	4.90
Medium	4.30	113	2.36	4.80
Heavy	4.40	129	2.36	5.00

Compacted mix properties according to AASHTO T245 with 100 blows per side

The higher void content indicated to reduction in compatibility of the mix and this result in low stabilities. When the three cement treated mixes are tested at equal void content, the effect of cement treatment is more evident and the stability values become higher compared to the light treatment mixes. The advantage of using coated cement aggregate in the concrete mix is its use in the hot climate weather with high stabilities and high void content. Also, reduction of bleeding is happened when the mixes of low void content post compacted under heavy traffic. The characteristics of compaction of the mixes are presented in Table 2 and Figures 2 and 3.

Table 2. Results of Compatibility tests

Treatment type and degree	Optimum asphalt (%)	Void content (%)	Voids filled with Bitumen (%)	Bulk specific Gravity (g/cm ³)	VMA
50 blows					
Untreated mix	4.5	3.5	74	2.41	14.5
Mix with hydrated lime, 1% cement	4.8	3.4	77	2.44	14.5
Mix with cement-coated aggregate	5.7	5.0	73	2.30	17.1
Heavy coat	5.7	5.7	68	2.31	17.7
75 blows					
Untreated mix	5.00	3.3	80	2.45	13.9
Mix with hydrated lime, 1% cement	4.8	3.1	80	2.46	13.9
Mix with cement-coated aggregate	5.1	4.5	71	2.38	16.3
Heavy coat	5.7	4.5	73	2.35	16.7

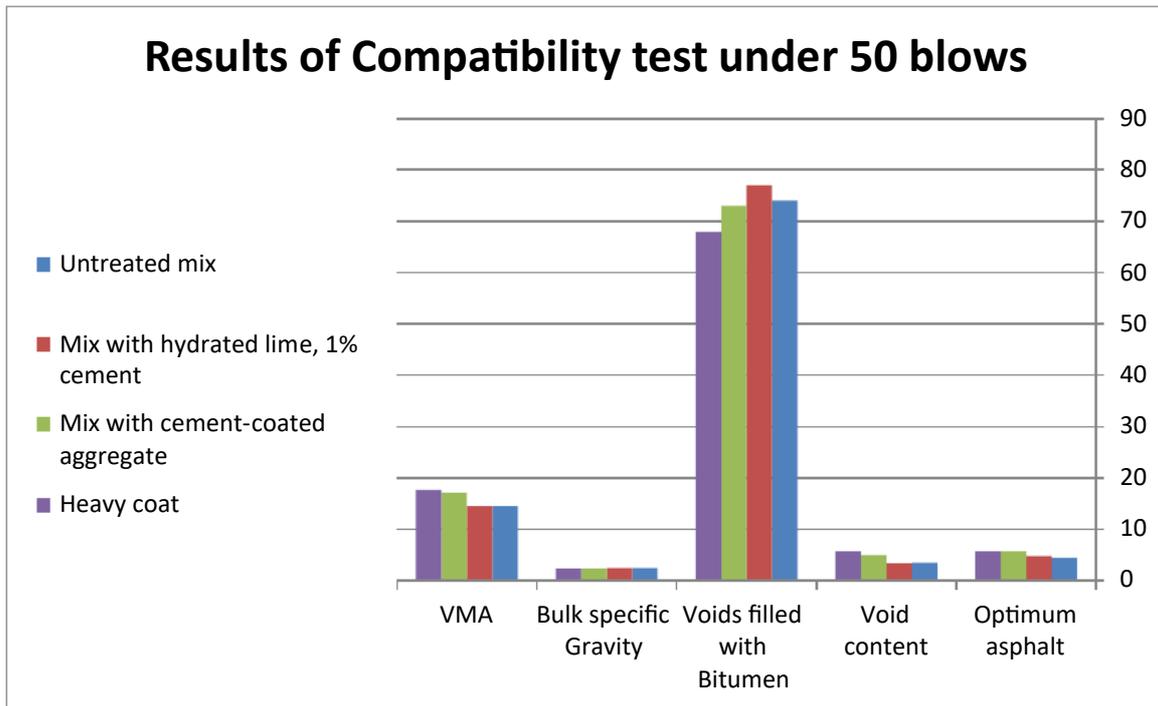


Figure 2. Results of Compatibility test under 50 blows

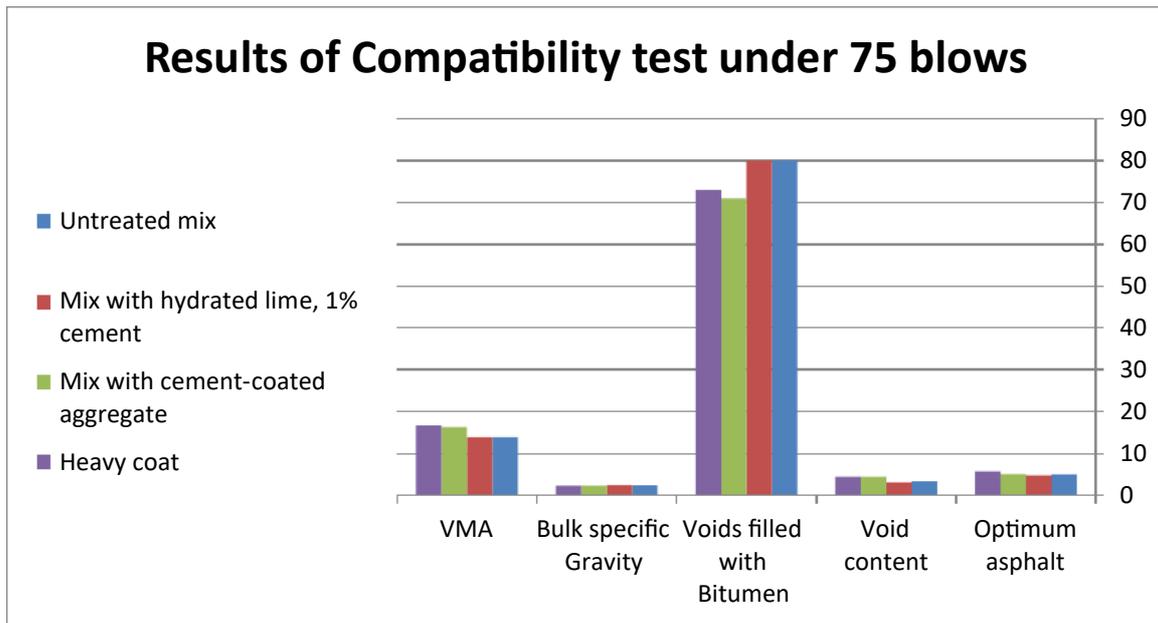


Figure 3. Results of Compatibility test under 75 blows

In Figure 2, the mixes with coated cement are about 25% higher in VMA than the ordinary mixes with the same gradation because VMA indicates to the degree of compatibility. Under a kneading type of compaction, this increase in VMA would probably be smaller because of the relative freedom of movement of the particles during the densification process.

In the extreme hot climate in Kuwait where the pavement temperature in summer may reach to 70 degrees, the concrete mix of the asphalt should have void content near to the upper limits as a safety factor against bleeding or potential fatting up. Increasing the blows to 75 will not effect on the asphalt content of different concrete mixes as shown in Table 2.

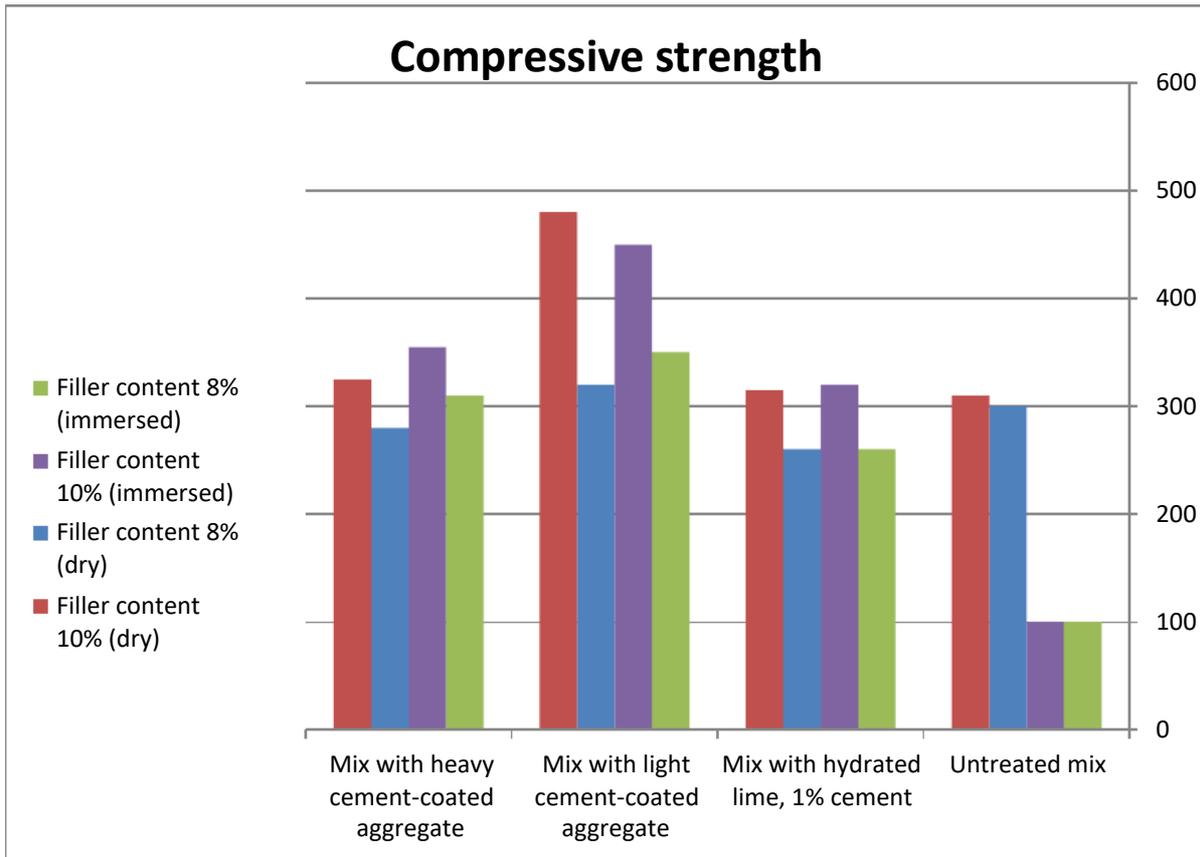


Figure 4. The effect of water immersion

The effect of water immersion is shown in Figure 4. Although the untreated specimens lose about 50% from its compressive strength and also the fatigue life but the hydrated lime and the cement coated aggregates increase the water resistance. The large decrease in strength of untreated specimens occurs in spite of their filler content of 8 and 10 % (mostly limestone dust), which should improve the mechanical component of adhesion and thus the resistance to stripping by increasing the viscosity of the original binder in the mix. There is a relation between the compressive strength and the fatigue life of the pavement concrete mix so increase or decrease in compressive strength affect directly with an inverse relationship of the fatigue life of the concrete mixes of the pavement as shown in Figure 5.

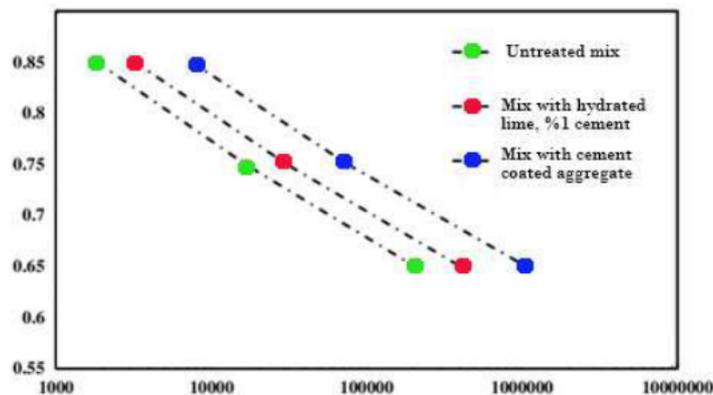


Figure 5. The fatigue life of the concrete mixes of the pavement

3.1. Quality control

In order to achieve its best performance, quality control programs should include the following [10-16]:

1. Experienced staff during the execution of the project
2. Efficient inspection Team
3. Clarity of Roles and Responsibilities for the project parties
4. Awareness of the regional conditions including; Soil Type, Temperature, and Traffic Volume
5. Awareness of Asphalt Quality and Type

REFERENCES

- [1] Huang, Y., Bird, R. N., Heidrich, O. "A review of the use of recycled solid waste materials in asphalt pavements". *Resources, Conservation and Recycling*, 52 (1), 2007, pp. 58-73.
- [2] Chen, Z., Wu, S., Xiao, Y., Zeng, W., Yi, M., Wan, J. "Effect of hydration and silicone resin on Basic Oxygen Furnace slag and its asphalt mixture". *Journal of cleaner production*, 112, 2016, pp. 392-400.
- [3] Liu, P., Hu, J., Wang, D., Oeser, M., Alber, S., Ressel, W., Falla, G. C. "Modelling and evaluation of aggregate morphology on asphalt compression behavior". *Construction and Building Materials*, 133, 2017, pp. 196-208.
- [4] Uzun, İ., Terzi, S. "Evaluation of andesite waste as mineral filler in asphaltic concrete mixture". *Construction and Building Materials*, 31, 2012, pp. 284-288.
- [5] Li, P., Ding, Z., Rao, W. "Evaluation of deformation properties of asphalt mixture using aggregate slip test". *International Journal of Pavement Engineering*, 17 (6), 2016, pp. 542-549.
- [6] Ahmedzade, P., Sengoz, B. "Evaluation of steel slag coarse aggregate in hot mix asphalt concrete". *Journal of hazardous materials*, 165 (1-3), 2009, pp. 300-305.
- [7] Pasetto, M., Baldo, N. "Influence of the aggregate skeleton design method on the permanent deformation resistance of stone mastic asphalt". *Materials Research Innovations*, 18(sup3), 2014, pp. S3-96.
- [8] Chen, Z., Wu, S., Wen, J., Zhao, M., Yi, M., Wan, J. "Utilization of gneiss coarse aggregate and steel slag fine aggregate in asphalt mixture". *Construction and Building Materials*, 93, 2015, pp. 911-918.
- [9] Button, J. W., Jagadam, V. "Cement coating marginal aggregates for use in asphalt pavements". Final report (No. FHWA/TX-93/1253-1F), 1992
- [10] Tenah, K. A. "How Is an Excellent Construction Inspector Developed?". In *Quality of Inspectors—In Search of Excellence* (pp. 18-31). ASCE, 1986
- [11] Warsame, A. "Framework for quality improvement of infrastructure projects". *Journal of Civil Engineering and Architecture*, 7 (12), 2013, pp. 1529-1539.
- [12] Fwa, T. F. "The handbook of highway engineering". CRC Press, 2005
- [13] Deacon, J. A., Monismith, C. L., Harvey, J. T., Popescu, L. "Pay factors for asphalt-concrete construction: effect of construction quality on agency costs". Report prepared for California Department of Transportation. Pavement Research Center, CAL/APT Program, Institute of Transportation Studies, University of California, Berkeley, 1997

- [14] Larsen, J. K., Shen, G. Q., Lindhard, S. M., Brunoe, T. D. “Factors affecting schedule delay, cost overrun, and quality level in public construction projects”. *Journal of Management in Engineering*, 32 (1), 2015, pp. 04015032.
- [15] Jha, K. N., Iyer, K. C. “Critical factors affecting quality performance in construction projects”. *Total Quality Management and Business Excellence*, 17 (9), 2006, pp.1155-1170.
- [16] Ebrahim Abu El-Maaty, A., Akal, A. Y., El-Hamrawy, S. “Management of Highway Projects in Egypt through Identifying Factors Influencing Quality Performance”. *Journal of Construction Engineering*, 2016.