ISSN 2278-3091
Volume 9, No.5, September - October 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse286952020.pdf
https://doi.org/10.30534/ijatcse/2020/286952020

# Improvement of the Physical and Mechanical Properties of Natural Asphalt Mixes Using Petroleum Bitumen and Polyethylene

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**ABSTRACT**
Natural asphalt is found in Syria in two separate and different locations, the first site is in Deir Ezzor city nearby Jabal al-Bishri region, and the other one is in Lattakia city, in the Kufra region. The current use of natural asphalt from these quarries is limited to paving secondary and rural roads with low traffic volume. The estimated reserve for both quarries is 110 million tons, which is sufficient to pave roads in Syria for the next 40 years. In this research, Al- Bishri natural asphalt was used, where the percentage of natural asphalt ranges between 15-22% of the entire mixture weight consisting of asphalt and sand. A six different proportions of Al-Bishri asphalt starting from 20% Al-Bishri asphalt and 80% of aggregates and increasing regularly by 5 % until it reaches 45% Al-Bishri asphalt and 55% of aggregates, i.e. (20-25-30-35-40-45) % of Al-Bishri asphalt and the remainder of aggregates. Petroleum asphalt was added to the Al-Bishri asphalt mixtures that were prepared at rates ranged from 5% to 45%, with an increase of 5%, i.e. 5% petroleum asphalt and 95% Al-Bishri asphalt, and so the higher the percentage of petroleum bitumen, the lower the Al-Bishri asphalt. The modified mixtures were formed from Al-Bishri and petroleum asphalt and polyethylene, in which polyethylene was added in proportions ranging from 0% 1.5%, 3%, 4.5%, and 6% of the percentage of petroleum asphalt added to Al-Bishri asphalt. Experiments have shown that the percentage of Al-Bishri asphalt added to aggregates reached 35% of the total weight of asphalt mixes. The percentage of petroleum asphalt added to the Al-Bishri asphalt reached 30%, and the percentage of polyethylene added to petroleum asphalt is 3% of the weight of petroleum asphalt. These percentages gave the max stability of 1700 kg, the maximum specific gravity of 2.35, and the void ratio of 4 %.

**Key words:** Natural Asphalt, Modified Asphalt, Petroleum Bitumen, Physical Properties, Mechanical Properties.

## 1. INTRODUCTION

Asphalt is usually used in road paving. It is extracted either naturally from asphalt lakes and sand and lime rocks impregnated with asphalt or industrially through the distillation of crude oil in oil refineries. In the United States of America (USA), the term asphalt is used for both natural and petroleum bitumen [1]. Bitumen is defined as a liquid, viscous, or solid organic material composed mainly of carbon and hydrogen with partial variables in its weights or derivatives, and it turns into a liquid state or increases its softness when exposed to high temperatures and possesses the property of adhesive and is produced by distillation of crude oil and can exist naturally [2]. As for industrial bitumen, it is produced from the remainder of the distillation of crude oil, and it needs high temperatures of 525 ° C to break it [3], [4].
Petroleum Refining Asphalt. Petroleum Bitumen produced from the crude oil refining process is the most used part in the construction of main, secondary, or agricultural roads in various countries of the world. The effect of heating in producing the asphalt differs on the various parts of hydrocarbons, some of which, if separated from the crude oil, become gaseous, some become liquid, and others solid. Each has a different boiling point, and this property is used in refining [5], [6], [7].
Natural Asphalt or Native Asphalt. Natural asphalt exists either in the form of asphalt lakes, as in some regions of the Caribbean, which has been used in the American, European, and Asian continents, or in the form of rock deposits impregnated with asphalt and was used in areas where these materials are found. Natural asphalt includes a wide range of naturally formed solid or semisolid materials, and they may exist either in a relatively pure state or may contain up to 50% or more of mineral substances [8].
The formation of the natural deposits of asphalt (bitumen) is due to the remains of ancient microalgae and other organisms that previously lived on the surface of the earth. Where the remains of living creatures after their death were deposited in the mud below the oceans or lakes, and they are the original habitats in which they lived, and under the conditions of heat, pressure, and the depth of burial in the ground, these remains turned into materials such as bitumen, kerosene or oil [3]. Natural asphalt materials have been known since ancient

times, and civilizations along the Euphrates have used these materials for nearly 6000 years, and the main use of these materials was as sealants, adhesives and some of these materials were and still are recycled as medicinal materials, and natural asphalt is relatively hard bitumen in the natural locations at 25 ° C and a viscous liquid at a 175 °C [8]. Some later examples show its cultural and historical significance. The first record of the use of asphalt materials (bitumen) by the Sumerians around 3000 BC, in different usages [9]. While, in the kingdoms of the Near East, natural asphalt was slowly boiled to get rid of the most weighty parts, leaving the material with a high partial weight and thermoplastic, and when it is coated with objects it becomes tough after cooling and then was used to coat the sheath cover of daggers and objects that need insulation from water [10]. Natural asphalt is found around the world in various countries in the form of lakes, as is the case in Trinidad's Pitch Lake, which is the most famous lake in the world [11], and in Bermudez Lake in Venezuela, and in the Dead Sea region between in Palestine and Jordan as well as it is found in Switzerland, and is found in northeastern Alberta, Canada [12]. As for Indonesia, there are two types of asphalt, which are hard and soft asphalt. In Syria, there are large quantities of natural asphalt in the areas of Jabal Al-Bishri and Kafraya. Natural asphalt is found in Syria in two separate and different locations, the first site in Deir Ezzor governorate in Jabal al-Bishri region, and the other site in Lattakia governorate, in the Kufra region. The current use of asphalt from these quarries is limited to paving secondary and agricultural roads with low traffic density. The estimated reserve for both quarries is 110 million tons, which is sufficient to pave roads in Syria for the next 50 years. After the big jump in global oil prices, serious consideration began to be given to the possibility of using it to pave the main roads at a relatively low cost and with a quality that meets the basic requirements of asphalt mixtures.

Al-Bishri Natural Asphalt. Al-Bishri natural asphalt quarry is located in the northwest of Deir Ezzor city, about 110 km in Wadi al-Qir and Shaafa al-Bishri. The estimated stock of human asphalt is approximately 100 tons. Natural human asphalt consists of siliceous sand impregnated with asphalt (bitumen), and human asphalt exists in the form of shallow or semi-surface deposits under a thin layer of sand. The average thickness of the asphalt-bearing layer is 3-4.5 m and may sometimes reach 13 m, and the bearing layers are distributed for asphalt on an area of up to 6 km2. The percentage of asphalt ranges between 17% -22% of the entire mixture weight of sand and asphalt [13]. The investment in the Wadi al-Qir site began at Shuafa al-Bishri in 1976 [14].

## 2. LITERATURE REVIEW

During the past three decades, the Ministry of Oil and Mineral Resources, the General Institution of Geology, and the General Asphalt Company have sought to develop the use of Al-Bishri asphalt in the paving of main roads. An economic technical study for using Al-Bishri asphalt for roads was prepared with a global expert house in 1986 to evaluate better economic alternatives. The main thing is by adding gravel materials with a known grain gradient as well as adding a specific percentage of petroleum bitumen, surface treatment, or using Al-Bishri asphalt for secondary irrigation canals. The study showed that the use of Al-Bishri asphalt in hot asphalt mixtures is the best economic alternative [13]. In 1992 another study was prepared by a researcher on natural Al-Bishri asphalt, in which asphalt mixtures were designed using 2/3 of locally available crushed gravel and granular materials with 1/3 of natural Al-Bishri asphalt of the total weight of the mixture. The study aimed to determine Marshall stability values for natural asphalt mixtures designed for secondary and agricultural roads (light traffic). The previous study showed that using natural asphalt mixtures has an economic savings of approximately 40 % over petroleum asphalt mixtures, in addition to improving the performance of these mixtures over mixtures that use individual asphalt [15]. The Roads Department in Technical Services Directorate carried out a study in 2006 entitled “The use of Al-Bishri asphalt in asphalt joints”. Natural asphalt was extracted from a mixture of sand and asphalt, and the percentage of natural Al-Bishri asphalt was between 17-22% of the total weight of sand and asphalt. After determining the physical properties, samples were prepared according to the Marshall method, where local calcareous stones with a known grain gradient were used and the proportion of Al-Bishri asphalt was from 25 to 45% of the entire weight, and the asphalt proportion of 35% has been adopted. This study recommended the use of Al-Bishri asphalt in the implementation of roads (local - agricultural - tourism) of light abundance and as a base layer in roads with high abundance and road maintenance work, and also recommended the follow-up of laboratory and practical experiments to improve the product and expand its application areas to reach its use by adding asphalt Oil or without addition in high volume roads [16]. In 2008 another research entitled "The use of natural asphalt in hot asphalt mixtures." was done where the physical, natural, and chemical properties of natural Al-Bishri asphalt were determined, samples that used Al-Bishri asphalt were tested individually according to the Marshall method, as well as the physical and mechanical properties of asphalt mixtures that used Al-Bishri asphalt with an average ratio ranging between 3.5-7% of the total weight of asphalt, and the gravel materials with different gradations of grains by the Egyptian specifications and comparison of the results with the international standards, and the economic evaluation of using these mixtures with petroleum bitumen mixtures was also compared. The principle of the tests was based on studying the effect of variable and repeated loads and different temperatures on laboratory samples. Experiments have shown that Al-Bishri asphalt cannot be used alone for any road as it is solid and tough asphalt. The performance of asphalt mixtures improved by adding 30% petroleum bitumen with a degree of penetration (200 to 250) or residues of usual lubricating oils by 6% of the weight of the asphalt material in the mixture and the possibility of using it in the main roads, as well as the economic savings of approximately 41% when using modified Al-Bishri asphalt mixtures for those that use petroleum bitumen [17].

In 2009 a study conducted by in the General Company for Roads and Bridges Al-Bishri asphalt raw material was heated and mixed with certain percentages of the asphalt of the refineries ranged from (5% - 10% -15% -20% up to 50%) of the weight of Al-Bishri asphalt, included in the formation of asphalt mixtures. Also, calcareous gravel materials available in the project area were used, and the percentage of basic asphalt and the physical and mechanical properties of asphalt mixtures were determined for the Marshall laboratory samples and their conformity with the conditions and specifications of the American Institute for Material Inspection and Testing (ASTM), at different stacking capacity and mixing temperature of 145 $^{o}$C. A field implementation upon one of the roads was paved with these mixtures. The project area (Aleppo-Raqqa road with a length of 3 km), was paved by these mixtures, underwent a high temperature of 43 $^{o}$C in summer, and decreased in winter to less than 5 $^{o}$C. Results after a year showed that the road subjection to loading conditions and the prevailing environmental and climatic factors have good resistance.

Investigates achieved by several dedicated groups show the possibility of adding the waste plastic in paving highways with good properties [17], [18]. The asphalt mixtures are carefully selected to confirm pavement performance throughout its service life [19], [20], [21]. One of the best important methods that leads to a decrease in landfills zone, it is the addition of West plastic to asphalt mixtures [22], [23], [24]. In recent times, new expertise have been implemented to produce innovative sources take out the recycling of some consumable materials to decrease the adverse effects of the accumulated waste plastic and decrease the necessity for natural materials [25], [26], [27].

## 3. RESEARCH METHODOLOGY

Natural asphalt mixtures consisting of Al-Bishri asphalt with aggregate materials: The Syrian technical specifications and conditions for the aggregates used in the formation of asphalt mixtures were adopted. The local crushed limestone materials available in the city of Aleppo were used, as they were brought from the Tamoura area, which is an area located about 25 km to the northwest of the city of Aleppo, and it is a homogeneous quality and is free of decaying stones, organic materials and harmful stones (the maximum diameter of the used gravel does not exceed 19mm). These aggregates must meet the appropriate technical conditions in terms of grain gradient, the shape of grains, corrosion resistance, and durability. Figure 1 shows the lower, upper, and middle limits of the gradient for the aggregates.

The first curve represents the upper boundaries (fine composition), while the second structure represents the lower limits of the values of the table (coarse composition). As for the third curve, it represents the mean of the upper and lower values of the two percentages that each sieve passes (average grain composition). In this paper, the mean value of the granular aspect of the aggregates was adopted. The natural aggregate and Al-Bishri sand properties display in table 1, Al-Bishri sand gradation shows in table 2, and physical properties of Al-Bishri and petroleum asphalt show in table 3. In terms of the shape of the grains, they are closer to the cubic shape, as for the percentage of aggregates, it was based on the previous granular composition and taking into account the use of six different proportions of Al-Bishri asphalt (sand + asphalt) starting from 20% Al-Bishri asphalt and 80% of aggregates and increasing regularly by 5 % until it reaches 45% Al-Bishri asphalt and 55% of aggregates, i.e. (20-25-30-35-40-45)% Al-Bishri asphalt and the remainder of aggregates, and gravel proportions are determined based on the type of granular composition and the asphalt ratios of each structure. Samples were compacted according to 75 blows on each face, as well as three temperatures of 155 for mixing, degrees Celsius were used.

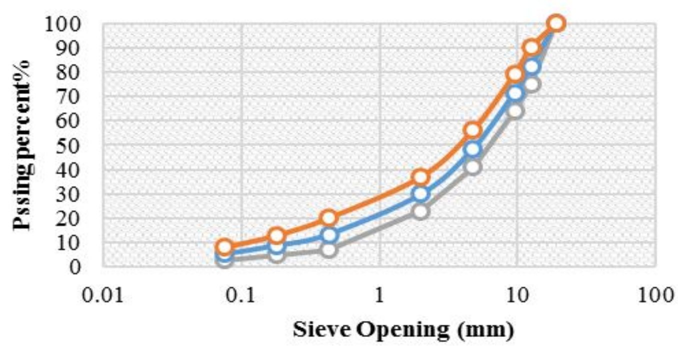


**Figure 1**: Lower, upper, and middle limits of the gradient for the aggregates

**Table 1**: Natural aggregate and Al-Bishri sand properties

| Specifications | Methods | Values |
|---|---|---|
| Abrasion Aggregate | ASTM C131 | 32.73 % |
| Magnesium sulfate treatment | ASTM C88 | 8.69 % |
| Sand equivalent | D2419 ASTM | 42.3% |
| specific gravity of the gravel The materials reserved on sieve No. 4 | C127 ASTM | 2.485 |
| specific gravity of the fine The materials reserved on sieve No. 4 | C128 ASTM | 2.642 |
| specific gravity of the The passing from Albeshri sand sieve No. 4 | C128 ASTM | 2.56 |
| The specific gravity of filler passing from sieve No. 4 | ASTM C128 | 2.717 |

**Table 2**: Al-Bishri sand gradation

| # Sieve | # 4 | # 8 | # 16 | # 30 | # 50 | # 100 | # 200 |
|---|---|---|---|---|---|---|---|
| % Passing | 100 | 100 | 98.7 | 97 | 65.3 | 8.4 | 0.7 |

**Table 3**: Physical properties of Al-Bishri and petroleum bitumen

| Examination | Measured value | | Standard value | Standard Method |
|---|---|---|---|---|
| | Natural asphalt | petroleum Bitumen | | |
| Specific Gravity/density @ 25º C | 1.14 | 1.03 | >1 | ASTM D-70 |
| Softening Point (R&B), º C | 59 ºC | 52 ºC | ≥48 | ASTM D-36 |
| Ductility (@ 25 º C, 5 cm/min) cm) | 60 cm | 79 cm | >100 | ASTM D113 |
| Penetration (@ 25º C, 5 seconds, 100) | 37 | 65 mm | 60-70 | ASTM D-5 |
| Fire point (º C) | 376 ºC | 313 ºC | 300 | AASHTO T48 |
| Flash point (º C) | 324 ºC | 298 ºC | ≥232 | AASHTO T48 |

The modified mixtures were formed from Al-Bishri and petroleum asphalt and polyethylene according to the proportion of optimum asphalt 35% of Al-Bishri asphalt. Petroleum Bitumen was added to the Al-Bishri asphalt mixtures that were prepared at rates ranging from 5% to 45%, with an increase of 5%, i.e. 5% petroleum Bitumen and 95% Al-Bishri asphalt, and so the higher the percentage of petroleum asphalt, the lower the Al-Bishri asphalt. Polyethylene was added in proportions ranging from 0%, 1.5%, 3%, 4.5%, and 6% of the proportion of petroleum asphalt, where polyethylene was mixed with petroleum Bitumen first, and then both were mixed with Al-Bishri asphalt in a special mixer, and then petroleum asphalt and polyethylene were heated with manual mixing at 170 ° C for two minutes and then placed in the mixer for three minutes, then polyethylene and petroleum Bitumen were mixed with Al-Bishri asphalt in the mixer for two minutes. Al-Bishri asphalt is a hard asphalt compared to the Bitumen of petroleum with a Penetration degree of (70-60).

## 4. RESULTS

### 4.1 Natural Asphalt Mixes:

The specific gravity increases by increasing the percentage of Al-Bishri asphalt until reaching a maximum value, as shown in Figure 2. After that, the specific gravity declines with the rise in the asphalt proportion. This is because the asphalt initially helps sliding aggregates, thus increasing the specific gravity until reaching the maximum value, after that, asphalt action is reversed by separating the aggregates, thus reducing the specific gravity. The increase in the stability to a maximum value and its decrease can be explained by the same previous mechanism, Figure 3. Increasing the percentage of Al-Bishri asphalt leads to a decrease in Void Ratio (Va) values, which is due to filling the spaces between the aggregates, as shown in Figure 4. The value of flow increases with the increase in the percentage of Al-Bishri asphalt because of the increase in the asphalt percentage, the slippage between grains increases, thus increasing the flow, as shown in Figure 5. The void mineral aggregate (VMA) decreases with increasing the percentage of Al-Bishri asphalt until reaching a minimum value as shown in Figure 6, and then the values of VMA increase with the increase in the percentage of asphalt and this is explained by the fact that asphalt initially helps to ease the sliding of grains, i.e. good interference and interlocking between the grains, which leads to a decrease in the VMA value until it reaches a minimum value, after which the asphalt takes a reverse action as it leads to the spacing between the grains, meaning an rise the VMA. As Al-Bishri asphalt proportion increase, the proportion of voids filled with asphalt (FVA) increase within the asphalt mixtures, as shown in Figure 7. From the above, it can be determined the optimum proportion of Al-Bishri asphalt, which was 35% of the entire asphalt mixture.

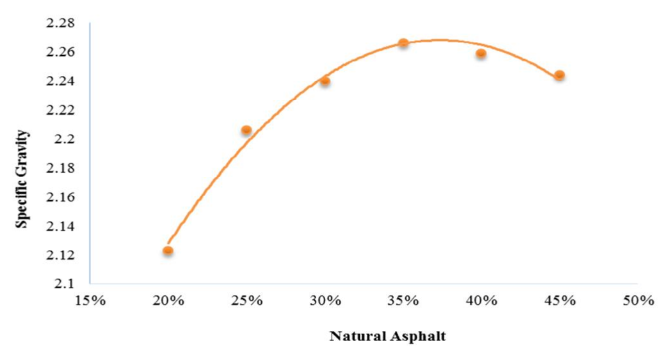


**Figure 2**: Specific gravity Vs natural asphalt content

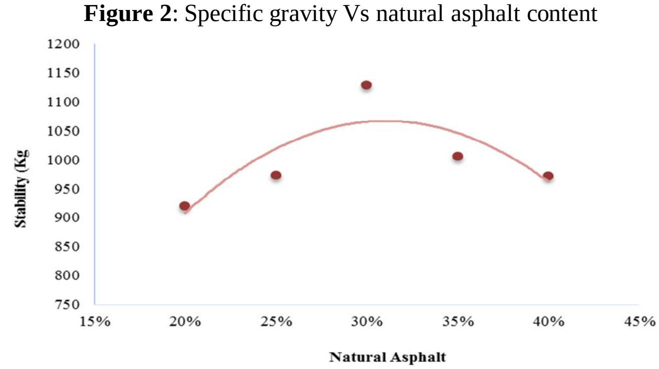


**Figure 3**: Stability with natural asphalt (%)

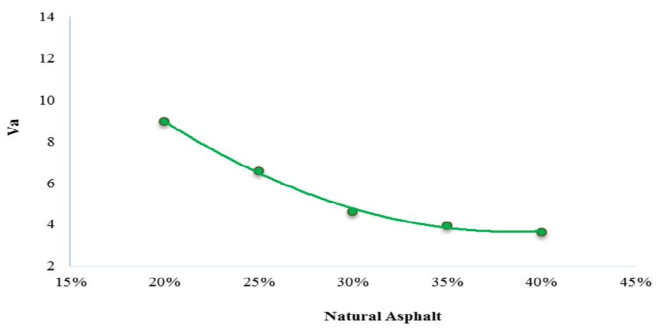


**Figure 4**: Void ratio with natural asphalt (%)

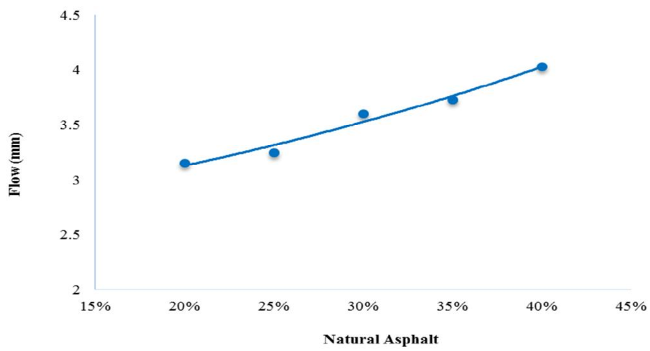


**Figure 5**: Flow with natural asphalt (%)

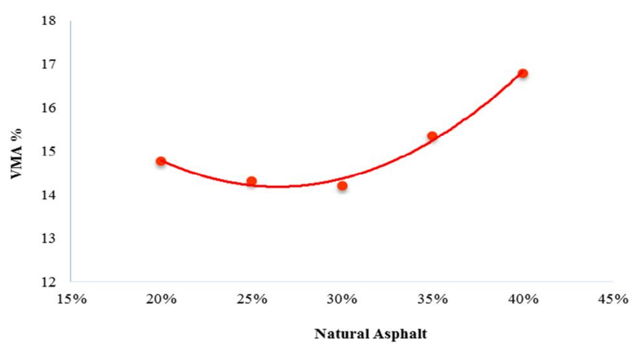


**Figure 6**: VMA with natural asphalt (%)

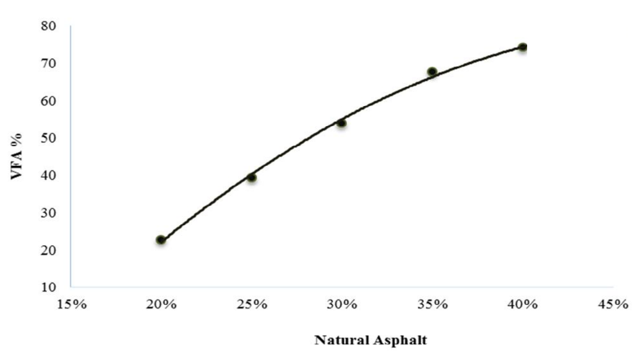


**Figure 7**: VFA with natural asphalt (%)

### 4.2 Modified Asphalt Mixes:

In this type of asphalt mixtures, 35% of the Al-Bishri asphalt was added to the aggregate materials, and then petroleum bitumen and polyethylene were added to the Al-Bishri mixtures. Physical and mechanical properties are determined. It is noticed that the specific gravity at 30% of petroleum Bitumen and 3% polyethylene has the higher value, due to the decrease in the viscosity of Al-Bishri asphalt when adding petroleum Bitumen and polyethylene, so it becomes more capable of covering the of aggregate and ease of sliding and interlocking between them, until the increase petroleum Bitumen and polyethylene become the opposite, the value of the specific gravity decreases, as shown in Figure 8. The increased stability can be explained by the same previous mechanism because each petroleum Bitumen and polyolefin increase the adhesion property and cohesion properties of natural asphalt and lead to increased stability at 30% petroleum Bitumen 3% as revealed in Figure 9. This is due to the formation of very small parts of polyethylene inside the asphalt mixtures, which leads to the hardness of asphalt, in addition to the increase in petroleum bitumen leads to a decrease in stability because the aggregate becomes floating (The aggregate diverge from each other) in the asphalt. The increase in the percentage of petroleum Bitumen and polyethylene added to Al-Bishri asphalt leads to a decrease in the ratio of Va as display in Figure 10.

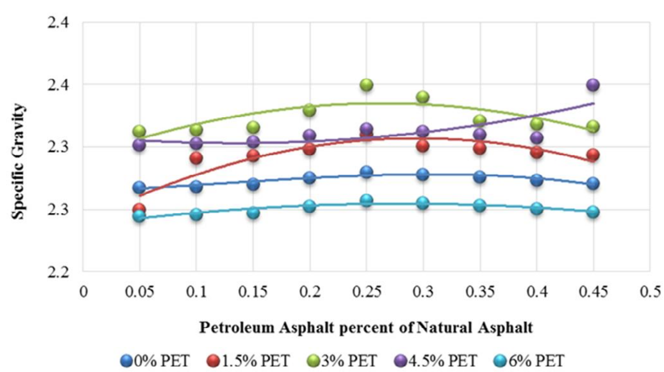


**Figure 8**: The specific gravity Vs petroleum Bitumen and polyethylene content

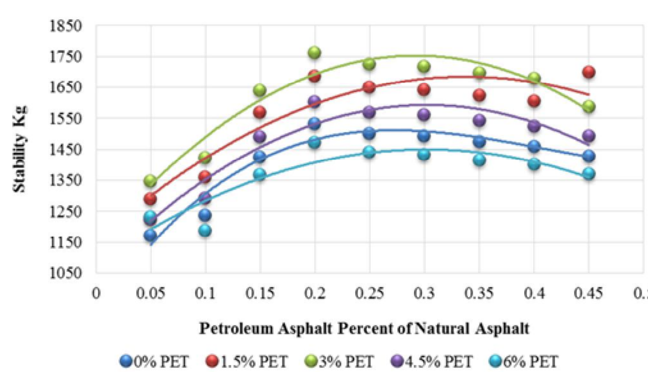


**Figure 9:** The stability Vs petroleum Bitumen and polyethylene content

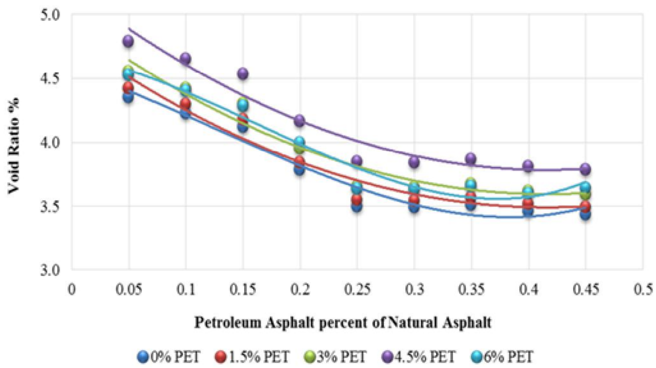


**Figure 10:** Va Vs petroleum Bitumen and polyethylene content

## 5. CONCLUSION

Results of the various tests carried out in this research showed that the use of polyethylene and petroleum Bitumen as a modifier for Al-Bishri natural asphalt are effective and suitable for heavy traffic pavements. Experiments have also shown that the percentage of Al-Bishri asphalt added to aggregates reached 35% of the entire asphalt weight mixes. The proportion of petroleum Bitumen added to the Al-Bishri asphalt reached 30%, and the percentage of polyethylene added to petroleum Bitumen is 3% of the weight of petroleum Bitumen. The percentage of Al-Bishri asphalt extracted from samples composed of silica sand impregnated with Al-Bishri taken from a site close to Jabal al-Bishri was 17%, and the remaining percentage was silica sand with an open gradient of gradient located between sieve No. 16 and sieve No. 200.

## ACKNOWLEDGEMENT

The authors are grateful to the Middle East University, Amman, Jordan for their financial support for the publication of this research article.

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