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# "UTILIZATION OF INDUSTRIAL WASTE MATERIAL IN HIGHWAY CONSTRUCTION"

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## ABSTRACT

Highways play an important role in developing the country. Highways affect directly on the economy, society, culture and security, so the scientists are looking for developing the performance of highways and low maintenance cost. The main objective of this study is to modify the bituminous mixed by utilization of waste industrial materials. , There are many wastes industrial materials can be used in bitumen. A study has been carried out in this search to illustrate the use of fly ash, (byproduct of combustion Pulverized coal in power plants , it produced during combustion of coal in bituminous paving mixes), Silica Fume,( by- product of producing silicon metal or ferro silicon alloys in smelters using arc furnaces) . For comparison, control mixes with modified bituminous mixes has been considered. Marshall Test has been conducted for the purpose of mix design as well as appreciation of paving mixes. It is observed that the mixes with fly ash and silica fume as modifiers modify the properties compared to control mixes. In this paper Silica Fume and Fly Ash are used as a modifier. Marshall stability test was conducted according to( ASTM D 6927-06 ). The percentages of modified mixtures used are 2, 4, 6, 8 and 10 % by bitumen weight. The results showed that the Marshall stability modified with SF and F.A were increased by 18.4% and 22.3 % respectively. So, we can concluded that adding SF and FA to asphalt binder success in improving the properties of bituminous mixes for flexible pavement. Hence, it has been recommended to utilize Silica Fume and Fly Ash wherever available, not only reducing the cost of construction, but also solve the bituminous mixes properties.

***Keywords:*** Marshall Stability test, S.F, F.A, bituminous mixes, waste industrial material

## 1. Introduction

Highways are designed to resist cracking, rutting, fatigue and low temperature and other distress. These distresses reduce the qualification of the pavement and increasing the cost of maintenance, but we build highways to resist the highway distresses and increase the services life of the highways with low maintenance. Engineers and researchers are looking for new materials. It is very interested that a small amount of waste materials has a strong effect on the mechanical properties of the pavements. The main goal of this paper is the utilizing of industrial waste materials in highways in order to:

1) Reduce the cost of construction of highways.

2) Save the nature materials from the extinction.
3) Disposal waste materials.
4) Reduce environment pollution and water pollution.

Nowadays disposal of industrial waste material poses great risks and problems. These materials (especially non biological) are an essential source of environmental pollution and water pollution. Utilization of these materials in highway construction based on technical, economical, and environmental standards. Waste materials like industrial, agriculture, building and house hold. Industrial materials like Coal Ash, Silica Fume, cement kiln dust, blast furnace slag, glasses and photogypsum. The objective of using waste materials in highway constructions and others structure is to reuse waste material in modifying it to protective to human health and the environment. Pavements divided into two types' flexible pavements and rigid pavements. Flexible pavements are surfacing from bituminous materials, consist of aggregate (fine and coarse), and small amount of asphalt binder approximately (3.5 – 6) % weight of mix. The performance of pavement depended on the good bituminous mix to achieve strong , durable , resistance to fatigue and permanent deformations and it must be safe and friend to environment and economical. To fulfill these demands we head to bitumen modification. It can be made by using different modifiers. Therefore, choosing the right type of modifiers in asphalt mixtures improves the properties of bitumen, thereby enhancing the performance of the mixture. This study encourages the use of industrial waste to reduce the cost of construction flexible pavements and helps in preserve nature reserves. The modifying asphalt makes it possible to improve these properties.

**Bhanuprasad and Ganesh (2017)** said that utilization of the steel industrial waste material and power plant waste materials in highways reduce the pollution of environment. Utilization of industrial slag material is very less and we can replace the expansive soil rather than murrum [1].

**Patel et al. (2007)** utilized copper slag mixed with Fly Ash with ( 20% , 25 % , 30% , 35% and 40% ) and approved that the maximum CBR value of 32 for 80% copper slag and 20% Fly Ash [2]. **Havanagi et al. (2007)** said that 75% copper slag and 25% Fly Ash with ( 3-9)% cement modified the maximum angle of friction of 41° and UCS of 5698 kPa for 28 days curing period. They said that mixing with minimum 3% cement used in the base course of pavements [3].

**Abdel-Wahed et al. (2016)** said that utilization of cement dust or Portland cement as filler in hot mix asphalt improved the properties of bituminous mixes. The Marshall stability increased with increment of 16% and 25%respectively, the unit weight increased by 3.51% , 4.3% respectively and the flow decreased by 14% and 18%. Utilization cement dust improve the properties of bituminous mixes and it also a cleaner environment [4].

**Sharma et al. (2010)** showed that Fly Ash which has high calcium oxide is an important modifier dominated the strength qualifications of bituminous mixes and can be used up to percentage 7 % as a filler [5].

**Beeghly (2003)** gave an experiment-based observation that LFA (lime and Fly Ash) could reduce the cost of materials by up to 50% compared to Portland cement [6].

**Khodary (2016)** examined that using S.F in highways construction improve the properties of base-course and improve the strength and stability of the soil. CBR test was increased from (54 – 94.5)% by modified the base course soil with S.F [7].

**Al-Taher et al. (2018)** studied the performance of modified asphalt mixtures using different traditional and Nano additives and comparative the results. They reported that

Silica Fume is the best material that gave the best performance with median cost increase approximately (14%), and they showed that Lime, LDPE and rubber improved the mechanical and physical properties of asphalt mixes [8].

**Chauhan et al. (2016)** Stated that adding micro silica, lime and F.A to the black cotton soil improved the properties of the soil , the optimum percentages of F.A, micro silica and lime are 3%, 5% and 3% . Soaked CBR increased to 6.5 times and un-soaked CBR to 1.5 times of unmodified soil [9].

**Abd El-Aziz et al. (2004)** stabilized the clayey soil by using lime and S.F, and the swelling potential was reduced from 19% to 16% and the plasticity index was reduced , the optimum percentage was examined that lime and S.F (11% and 15%) respectively [10].

**Negi et al. (2013)** showed the effect of modifying the clayey soil with S.F and the potential swelling decreased and the optimum percentage of S.F was 20% , and CBR improved with 72% [11].

**Azzawi et al. (2012)** studied the change in the properties of silty clayey soils after mixing silica fume**.** They concluded that the swelling pressure and compressive strength of stabilized samples with silica fume, increasing in percentage of Silica Fume, the permeability of soil increased the surfaced cracks of compacted clay samples reduced by 75% with adding of silica fume [12].

## 2. Materials and methodology

### *2.1. Materials*

#### *2.1.1. Asphalt binder*

Asphalt binder used was asphalt cement grade (60 -70). It was brought from Suez City with specific gravity 1.02 which is used in roads construction in Egypt. Table (1) shows the physical properties of asphalt binder.

**Table 1.**
Properties of bitumen

| Property | AASHTO Designation No. | Result |
|---|---|---|
| Penetration value | T-49 | 66 |
| Softening point (°C) | T-53 | 52 |
| Kinematic viscosity | T-201 | 325 |
| Flash point | T-48 | 251 |

#### *2.1.2. Coarse and fine aggregates*

The properties of used aggregates are shown in Table (2). Coarse aggregates are filled by the fine aggregates. So the function of fine aggregates is to fill the voids of coarse aggregates. Coarse aggregate that retained on sieve No.4 but fine aggregates that passing sieve No.4 and retained on sieve No.200. The aggregates gradation was selected according to type (3D) which is one of the commonly used gradations of the Egyptian code for highway. The gradation of used aggregate showed in Table (3)

**Table 2.**
The properties of used ag gregates

| properties | Coarse Agg. (1) | Coarse Agg. (2) | Fine Agg. | limits |
|---|---|---|---|---|
| Los Angeles Abrasion value after 500 revolution | 25.5 | 26.17 | - | 40 Max |
| Bulk Specific Gravity | 2.56 | 2.55 | 2.65 | -- |
| Saturated and Dry Surface Specific Gravity | 2.6 | 2.59 | | -- |
| Apparent Specific Gravity | 2.68 | 2.65 | | -- |
| Water absorption (%) | 1.71% | 1.49% | | 5 Max |

**Table 3.**
The gradation of the Agg

| Type | Coarse aggregate | | | | Fine Agg. | | gradation of design mix | limits of Specification |
|---|---|---|---|---|---|---|---|---|
| | Agg. (1) | | Agg. (2) | | | | | |
| Sieve size (inch) | Passing % | 31% | Passing % | 41% | Passing % | 28% | | |
| 1 in | 100 | 31 | 100 | 41 | 100 | 28 | 100 | ( 100 ) |
| 3/4 in | 99.75 | 30.93 | 100 | 41 | 100 | 28 | 99.93 | ( 75 – 100 ) |
| 1/2 in | 41.95 | 13 | 100 | 41 | 100 | 28 | 82 | ( - - - - - ) |
| 3/8 in | 12.21 | 3.78 | 86.68 | 35.53 | 100 | 28 | 67.32 | ( 45 – 70 ) |
| No 4 | 1.12 | 0.34 | 10.5 | 4.3 | 99.3 | 27.8 | 32.45 | (30 – 50 ) |
| No 8 | 0 | 0 | 0.63 | 0.2583 | 95.26 | 26.67 | 26.93 | ( 20 – 35 ) |
| No 30 | 0 | 0 | 0.4 | 0.164 | 61.88 | 17.32 | 17.49 | ( 5 – 20 ) |
| No 50 | 0 | 0 | 0 | 0 | 35.35 | 9.89 | 9.89 | ( 3 – 12 ) |
| No 100 | 0 | 0 | 0 | 0 | 12.53 | 3.5 | 3.5 | ( 2 - 8 ) |
| No 200 | 0 | 0 | 0 | 0 | 4.2 | 1.76 | 1.176 | ( 0 - 4 ) |

### *2.1.3. Silica fume*

The silica fume as shown in figure (1) was used. It is produced by EFACO (Egyptian Ferro-Alloys Company). S.F: is a by- product of producing silicon metal or ferro silicon alloys in smeleters using arc furnaces. S.F contain silicon dioxide about (92-97) % . Its particles are very fine and spherical glassy. Its specific gravity is 2.15. It obtained from Sika Company - 1st Industrial Zone (A) - El Obour City - Cairo – Egypt. The physical and chemical properties of the silica fume supplies from Egyptian Ferro-Alloys Company (EFACO) showed in Table (4) ,[7].

**Table 4.**
The physical and chemical properties of the silica fume,[7]

| Property | Measured values | Limitations |
|---|---|---|
| Physical properties: | | |
| Color | Light gray | -- |
| Specific gravity | 2.15 | -- |
| Bulk density | 340 | 250-450 Kg/m$^3$ |
| Chemical properties: | | |
| $SiO_2$ | 97 % | 90 % min |
| C | 0.5 % | 1% max |
| $Fe_2O_3$ | 0.5 % | 1.5 % max |
| $Al_2O_3$ | 0.2 % | 1 % max |
| CaO | 0.2 % | 1 % max |
| MgO | 0.5 % | 1.5 % max |
| $K_2O$ | 0.5 % | 1.5 % max |
| $Na_2O$ | 0.2 % | 0.5 % max |
| $SO_3$ | 0.15 % | 0.2 % max |
| Cl | < 0.01 % | 0.05 % max |
| $H_2O$ | 0.5 % | 0.8 % max |
| PH | 6% | ±1 % max |

- From the Egyptian Ferroalloys Company (EFACO)

**Fig. 1.** Sample of Silica Fume

### *2.1.4. Fly ash*

It is a byproduct of combustion Pulverized coal in power plants. Fly Ash produced during combustion of coal. F.A Specific gravity is 2.0. The properties of the used F.A minerals are shown in Tables (5). Figure (2) shows F.A shape. Fly Ash gets from Sika Company - 1st Industrial Zone (A) - El Obour City - Cairo – Egypt.

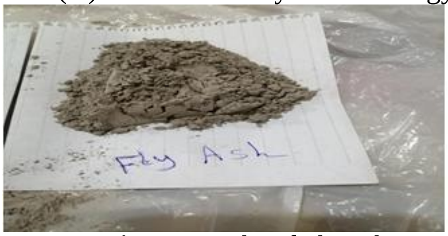


**Fig. 2.** Sample Of Fly Ash

**Table 5.**
Chemical properties of Fly Ash, [13]

| Oxide | Percent % | ASTM Requirement C618 (%) |
|---|---|---|
| $SiO_2$ | 61.95 | ------ |
| $Fe_2O_3$ | 2.67 | ------ |
| $Al_2O_3$ | 28.82 | ------ |
| $SiO_2$+ $Fe_2O_3$ +$A_2O_3$ | 93.44 | 70.0 min. |
| $Na_2O_3$ | 0.26 | 1.5 max. |
| CaO | 0.88 | ------ |
| MgO | 0.34 | 5.0 max |
| $SO_3$ | < 0.07 | 5.0 max |
| L.O.I | 0.86 | 6.0 max |

### *2.1. Preparation of Marshall specimens*

Marshall Specimens were prepared according as (ASTM D 6927-06). Fine and course aggregates approximately (1100 gm) were put in the pan. The aggregates were heated to temperature (160) °C. The compaction mold assembly were cleaned and pre-heated in the oven. Asphalt binder (60-70) was heated to (150) °C. The asphalt binder was added to the heated aggregates and mixed rapidly. The paper with the form number was placed below the mold. The mixture was placed in the mold and stirred by spatula for (15) time around the surrounding and (10) times over the interior carefully. The spatula was removed and the surface was smoothed, then the paper with the number of form was placed above the mixture in the mold. The mold was compacted with 75 blows on the two sides. Next the samples were moved to smooth table at room temperature for a night. The specimens were taken out of the mold. The specimens were weighted in air, and were placed in water for 2 minutes and weighted and finally weighted in basket to calculate bulk density, as shown in figure (3).

- **Preparation of plain specimens** : three unmodified specimens were prepared for various asphalt content ( 3.5 , 4 , 4.5 , 5 , 5.5 )%
- **Preparation of modified specimens** : in this study modified specimens were prepared with S.F and F.A . The percentage of modifier were added ( 2 , 4 , 6 , 8 , 10 )% by the weight of asphalt binder as shown in Table (6)

**Table 6.**
Weights of AC and F.S in the Mixes of First Group (AC 3 .5%)

| Percentage of modifier | Asphalt cement ( g) | Modifier ( gm ) | Total weight of modified AC |
|---|---|---|---|
| 2% | 37.73 | 0.77 | 38.5 |
| 4% | 36.96 | 1.54 | 38.5 |
| 6% | 36.19 | 2.31 | 38.5 |
| 8% | 35.42 | 3.08 | 38.5 |
| 10% | 34.68 | 3.82 | 38.5 |

Five groups of modified samples were prepared with various asphalt content. Every group contained three specimens. For this method 75 modified specimens with Silica Fume were prepared and 75 modified specimens with Fly Ash.

### *2.2. Marshall test*

The specimens were submerged in a bath of water of (60) °C for period 30 minutes. Then the specimens were removed from the bath and placed in Marshall Stability test at maximum time 30 seconds from the time removing the samples from the bath water. Three specimens for each combination were prepared and average results are reported as shown in figure (3).

**Fig. 3.** Marshall Procedure

## 3. Results and discussion

Mixtures with five different asphalt binder content (3.5, 4, 4.5, 5, 5.5) were prepared and tested. The properties such as Bulk density, air voids, VMA, Marshall Stability and Flow value were analyzed for Silica Fume and Fly Ash as modified bitumen in various proportions (2%, 4%, 6%, 8%, 10%) for 3.5%, 4%, 4.5%, 5% and 5.5% bitumen content. The results of using Silica Fume were showed in figures (4) to (8). Also, the results of using Fly Ash were showed in figures (9) to (13).

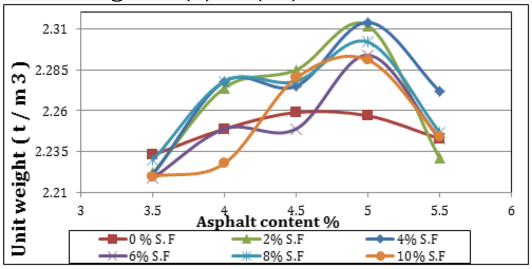


**Fig. 4.** Variation of unit weight with AC % modified by S.F

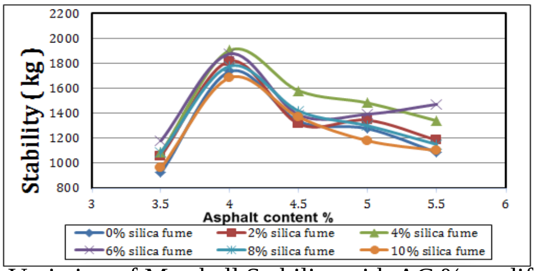


**Fig. 5.** Variation of Marshall Stability with AC % modified by S.F

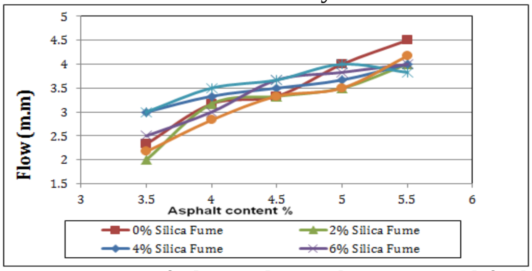


**Fig. 6.** Variation of Flow value with AC % modified by S.F

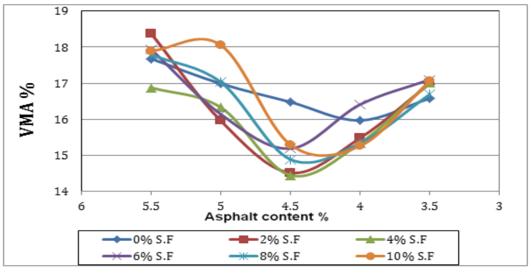


**Fig. 7.** Variation of VMA% with AC % modified by S.F

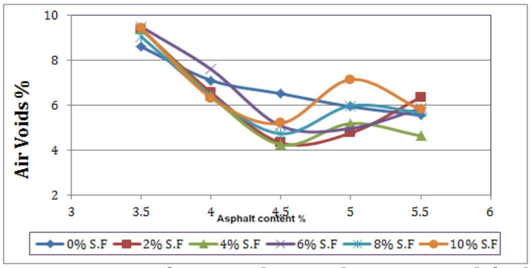


**Fig. 8.** Variation of Air voids% with AC % modified by S.F

As shown from figures (4) to (8) it observed that when the percentage of Silica Fume increases the stability and Bulk density increased till 4% S.F and then decreased. Unlike, adding Silica fume to the asphalt mixture leads to decrease the flow, AV % and VMA%. The max. Stability recorded as 1902.9 Kg for 4% Silica Fume at 4% AC and the max. bulk density recorded as 2.314 for 4% Silica Fume at 4.5 % AC.

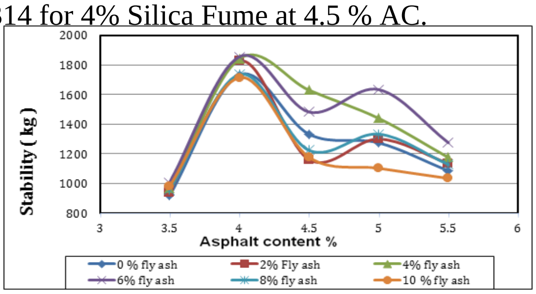


**Fig. 9.** Variation of Marshall Stability with AC % modified by F.A

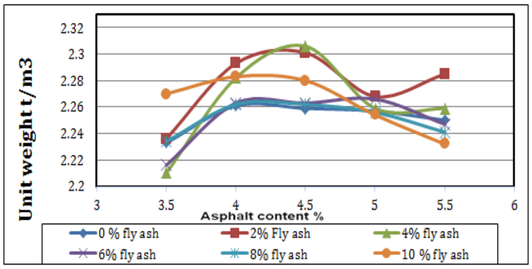


**Fig. 10.** Variation of unit weight with AC % modified by F.A

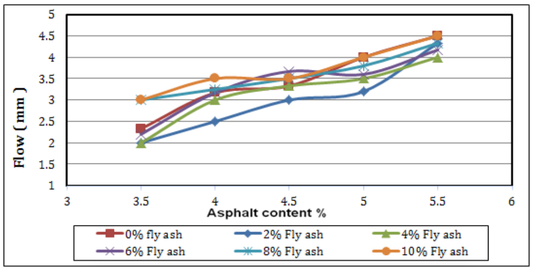


**Fig. 11.** Variation of Flow value with AC % modified by F.A

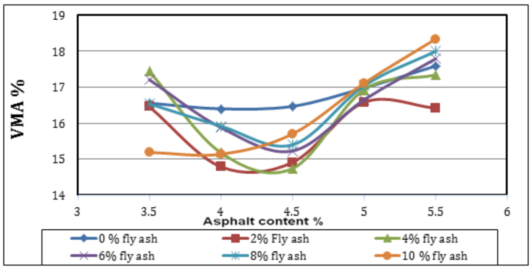


**Fig. 12.** Variation of VMA% with AC % modified by F.A

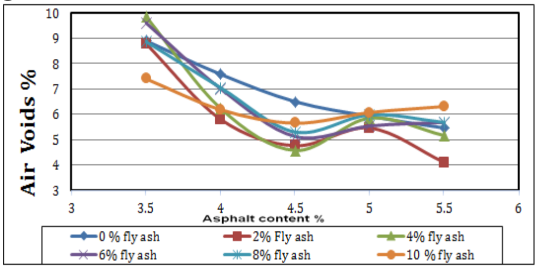


**Fig. 13.** Variation of Air voids% with AC % modified by F.A

As shown from figures (9) to (13) it observed that when the percentage of Fly Ash increases the stability and Bulk density increased till 4% Fly Ash and then decreased.

Unlike, adding Fly Ash to the asphalt mixture leads to decrease the flow, AV % and VMA%. The max. Stability recorded as 1856.4 Kg for 6% Fly Ash at 4% AC and the max. bulk density recorded as 2.306 for 4% Fly Ash at 4.5 % AC.

**Comparison between the results of Silica Fume and Fly Ash as a modifier:**

As shown from Figure (14), the comparison between control mix and the optimum of each Silica Fume and Fly Ash were conducted. It noticed that, using Fly Ash or silica fume as a modifier increased markedly either Marshall Stability or unit weight. On the other hand, VMA% and AV were decreased and the flow still keeping within the acceptable limits.

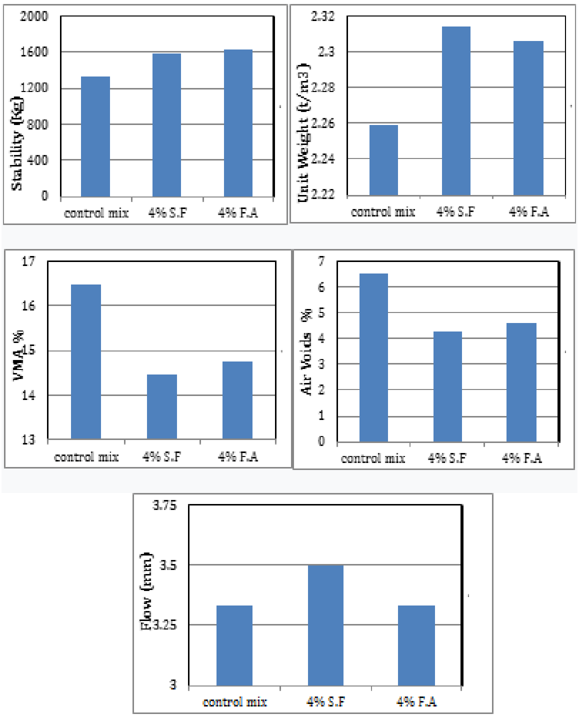


**Fig. 14.** Comparison between control mix, S.F and F.A

## 3. Conclusions and recommendations

### *3.1. The following conclusions can be drawn from the study:*

1) Utilizing waste materials in highway enhance the performances of pavements
2) Silica Fume and Fly Ash can be used in bituminous mixes modifier they improve the qualifications of Marshall test
3) Adding S.F to asphalt binder increases Marshall stability to about 18.4%
4) Modifying asphalt binder by using Fly Ash increases Marshall Stability to about 22.3 %.
5) O.A.C is 4.5 %, Optimum Fly Ash modifier content at 4% by weight of asphalt binder.
6) Results of Marshall Test showed that the modified specimens prepared based on 4% Silica Fume gave a good results compared to other various percentage.
7) Modification of the bituminous concrete mixture has led to maximum stability with a lower bitumen content, which solves the global oil crisis

### *3.2. Recommendations*

1) It is recommended to study the performances of modifying bitumen by Super-pave mix design
2) It is recommended to mix Fly Ash with Silica Fume to get a new modifier for asphalt binder
3) It is recommended to modify bitumen by another types of modifier such as crumb, fiber and tires

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## استخدام المخلفات الصناعيه في بناء الطرق السريعه

**الملخص**

تلعب الطرق السريعة دورًا مهمًا في تنمية البلاد. تؤثر الطرق السريعة بشكل مباشر على الاقتصاد والمجتمع والثقافة والأمن ، لذلك يبحث العلماء عن تطوير أداء الطرق السريعة وتكلفة الصيانة المنخفضة. الهدف الرئيسي من هذه الدراسة هو تعديل البيتومين الممزوج باستخدام المواد الصناعية المهدورة. ، هناك العديد من النفايات يمكن استخدام المواد الصناعية في البيتومين. تم إجراء دراسة في هذا البحث لتوضيح استخدام الرماد المتطاير (نتيجة ثانوية للفحم المسحوق المحترق في محطات توليد الطاقة ، التي أنتجت أثناء احتراق الفحم في خلطات الرصف البيتومينية) ، غبار السيلكا ، (منتج ثانوي لإنتاج معدن السيليكون أو السبائك الحديدية الحديدية في المصاهر باستخدام أفران القوس). للمقارنة ، وقد تم النظر في مزيج التحكم مع مزيج البيتومين المعدلة. لقد تم إجراء اختبار مارشال بغرض تصميم المزيج بالإضافة إلى تقدير خلطات الرصف. يلاحظ أن الخليط مع الرماد المتطاير وأبخرة السيليكا حيث تعدل المعدلات الخواص مقارنة بمزج التحكم. في هذه الورقة ، يتم استخدام غبار السيلكا و الرماد المتطاير كمعدل. تم إجراء اختبار ثبات مارشال وفقًا لـ (ASTM D 6927-06). النسب المئوية للمخاليط المعدلة المستخدمة هي 2 و 4 و 6 و 8 و 10 ٪ من وزن البيتومين. أظهرت النتائج أن استقرار مارشال المعدل مع SF و F.A قد زاد بنسبة 18.4 ٪ و 22.3 ٪ على التوالي. لذلك ، يمكننا توصيل ذلك بإضافة SF و FA إلى نجاح رابط الإسفلت في تحسين خصائص الخلائط البيتومينية للرصيف المرن. وبالتالي ، يوصى باستخدام غبار السيلكا و الرماد المتطاير حيثما كان ذلك متاحًا ، ليس فقط لتقليل تكلفة الإنشاء ، ولكن أيضًا لحل خصائص الخلطات البيتومينية.

***كلمات البحث:*** *الرماد المتطاير, غبار السيليكا ، النفايات الصناعية ، تصميم الرصيف.*