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Design and Environmental Effect of Residual of Water Purification plants on Asphalt Mix Design by Marshall Method.

تأثير المخلفات الناتجة من محطات تنقية المياه على البيئة وعلى تصميم الخلطات الأسفلتية المصممة بطريقة مارشال

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KEYWORDS:
Residuals, hot mix asphalt, Marshal test, stability, flow, water treatment plant.

الملخص العربي - مؤخرا، من أجل إستمرارية البيئه والحد من إستهلاكها، توجهنا إلى تبديل المواد بإعادة إستخدام المخلفات ،والتى تحقق قيمه اقتصاديه وبيئيه عاليه، وتم الالتفات لهذا المبدأ بصوره محليه ودوليه، مؤخرا تم إعتبار الحمأه الناتجه عن عملية تنقية المياه ملوث بيئي، هذا البحث يدرس مدى إمكانية إعادة إستخدام الحمأه فى عملية تصنيع الخلطة الأسفلتيه لتقليل التأثير السلبى للحمأه على البيئه وإذا أمكن تحسين خواص الخلطة الأسفلتيه، تم إستخلاص عينات الحمأة من ثلاث محطات لمعالجة مياه الشرب وهم: "محطة المنصوره لمعالجة مياه الشرب ومحطة ميت فارس لمعالجة مياه الشرب ومحطة جاليا لمعالجة مياه الشرب"، الحمأه من كل محطه تم إضافتها بنسب 5، 10 و 15% من إجمالى وزن رمل الكسارات، وأن التغيير فى خواص اختبار مارشال تحمل نفس الشكل والأداء بشكل كبير، حيث أن زاد كل من خواص الثبات ونسبة فراغات الهواء وفراغات الهواد بين الركام والمادة اللاحمة بينما قل كل من خواص التدفق والكثافه ونسبة فراغات الهواء داخل أجزاء الركام، فأثبتت الدراسات القيمة العظيمة التى تضيفها إضافة الحمأه الناتجه من معالجة مياه الشرب إالى الخلطة الأسفلتية من حيث الحفاظ على البيئه واستمرارها وتحسين الخلطة الأسفلتية إن أمكن

***Abstract*—For a sustainable environment, in recent years, the replacement of natural raw materials with new alternative materials, which acquire an economic, energetic and environmental value, has gained more national and international attention. Recently, water residuals had considered as an environmental pollutant. This paper investigates the reuse of water residuals in hot mix asphalt industry to reduce the negative effect of the residuals on the environment and, if possible, improve mix properties. Residuals have been obtained from three Water treatment plants "El-Mansoura water treatment plant, Meit Fares water treatment plant and Galia water treatment plant". The residuals from each plant has been added at different percent 5, 10 and 15% to the crushers' sand in the hot mix asphalt. The Main behavior of residual mixes properties is generally having the same trend. It's noticed that the stability, air voids and V.MA have increased but the flow, bulk density and V.F.A have decreased. The studies proved the great value obtained due to adding residuals to asphalt mixes from the point of sustainable environment and improving properties of hot mix asphalt.**

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I. INTRODUCTION

WATER treatment residuals represent the by-product produced during the treatment of potable water. Water treatment residents are composed of aluminum or iron based salts, which are used as coagulants to remove color, turbidity and human substances and high concentration of suspended solids. Total organic carbon and in organic as well [1]. Large quantities of water treatment residuals are produced daily. Traditionally, water residuals have been discharged to downstream of the water canal. This causes environmental problems such as aquatic life risk, change the nature of the water stream (color, suspend solids concentration, turbidity in organic concentration and cause public health risks [2].

Current legislation classifies water residuals waste which is usually dewatered before disposal in landfills or incinerations.

According to the Czech statistics office, the Czech Republic produces 34,494 tons of water treatment residuals in 2006. Netherlands spent a huge sum of 30-40 million euro per year for sludge disposal. Portugal estimate the amount of water residuals produced per year around 66,000 ton. Therefore, it is of a great importance to find a cost effective and eco-friendly disposal, regeneration, or reuse option for water residuals as it becomes a significant environmental issue.

There are numerous research studies on sewage sludge utilization [64] but limited information about water residuals reusing and recycling even in recent literature. Although, there are some investigations on potential industrial utilization of water residual success pottery industry, cement production, dust control on power plants, glass ceramic industry. Water residuals has been used a soil conditioner in agriculture and also used for the removing of some pollutant from wastewater [64].

The waste materials that be used in hot mix asphalt industry can broadly be categorized as shown in figure (1). Many studies have been conducting in using waste materials in hot mix as asphalt and most of there have achieved satisfied results

The objective of this research is to investigate the use of water residuals in hot mix asphalt for three water treatment plants with varies addition percent from the crushers' san ranged from 5 to 15%.

II. METHODOLOGY

Water treatment residual samples had been obtained from three different Water treatment plants. El-Mansoura treatment plant, Abo Fares treatment plant and Galia treatment plant. The Residuals had been heated up to 60ºC for 24 hours for dewatering. Afterwards, the residuals had been cooled for 12 hours then, crushed through a crusher and had been sieved on the sieve number 4.

The three plants are using the conventional system to treat the potable water. The average dosage of Alum added in the three water treatment plants in 20 mg/l. The raw water of Galia, Mansoura and Meit Fares water treatment plants are Mansouria canal, the Nile River and bahr Tanah canal respectively. The flow rate of Galia, Mansoura and Meit Fares are 34,560, 103,000 and 100,000 m^3/day respectively. The turbidity of

The practical percent of Residuals in asphalt mixes must not exceeding 25% of sand weight replacement [55], the excess of Residuals percent in mix over that ratio increase the required asphalt needed for bonding mix components to each other, and so make the mix becomes nerveless. Figure 2 outlines the experimental work had done in this research.

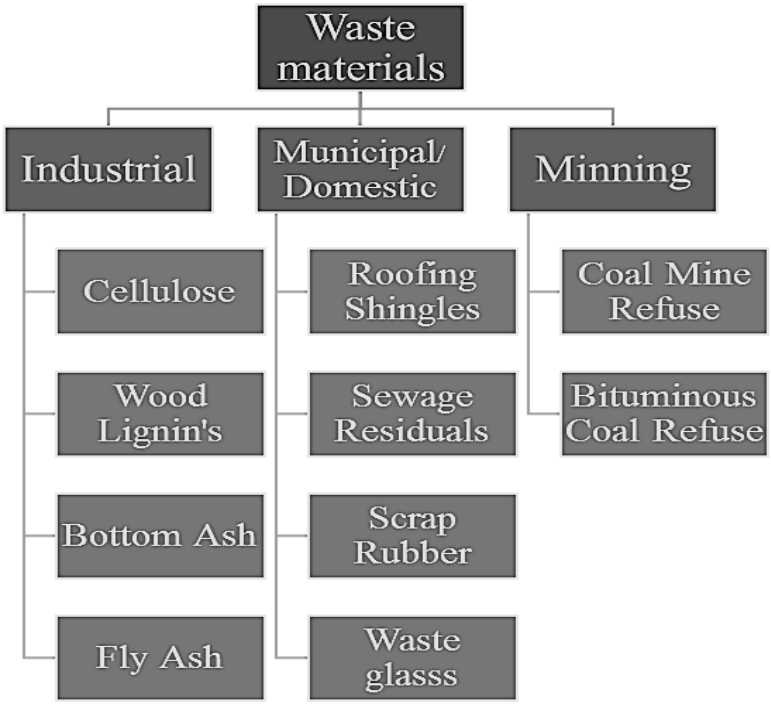

Figure 1: waste materials used in hot mix asphalt industry

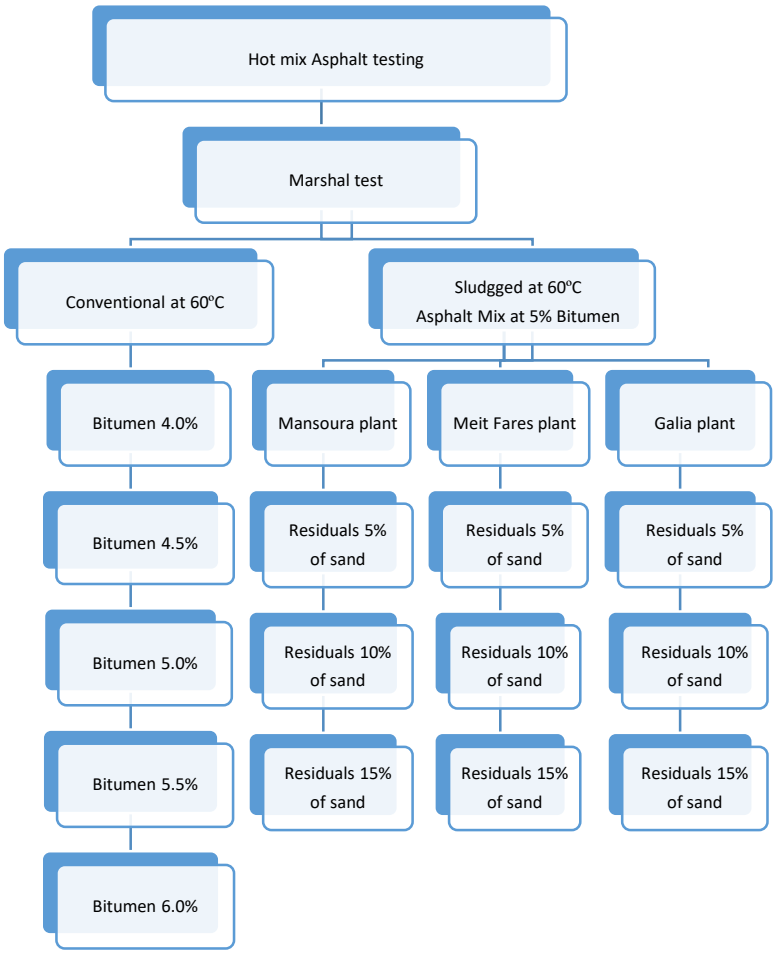

Figure 2: The Experimental methodology of the research

The evaluation of this study passed through a series of tests that can be classified into categories:

1. Material testing evaluation (Coarse aggregates, fine aggregates, mineral filler and dried Residuals).
2. Trail residuals mixes to determine the approximate values of replacing sand by dried Residuals. So, Residuals was added to the gradation at three different percent ratios (0, 5, 10 and 15) instead of an equal amount of sand.
3. Design of asphalt mixes (dense graded mix "4-C") for both conventional and residual mixes.
4. Testing the conventional asphalt mixes using "Marshal test at 60ºC curing temperature".
5. Testing asphalt mixes with the Residuals samples from the three water treatment plants using "Marshal Test at 60ºC curing temperature".

In producing hot mix asphalt, aggregate is dried and heated up to a temperature equals 150ºC. Asphalt cement (Bitumen) is also heated to reach a viscosity of 280±30 stocks then mix of aggregate and asphalt prepared.

Based upon that, a mixing temperature of approximately 150º is specified by different road agencies specifications such as the American Association for state highway and transportation (ASHTOO), The American society for testing and materials (ASTM) and the Egyptian roads and bridges authority (EBRA). This mixing temperature is considered the most suitable to produce a mix with the required properties [59].

In drying process, all free water evaporates as the temperature reaches 110ºC [59]. As temperature increases more than 110ºC part of the mechanical bond water evaporates also. Evaporating the free water from aggregates particles gives the asphalt cement the chance to bind them. In the case of highly absorptive aggregate, Goshorn and Williams [60] showed that absorbed asphalt increased with the increase of mixing temperature.

To find the optimum percent of Bitumen for the asphalt

mix it should be making sieve analysis for the aggregates in the automatic sieve analysis to find the perfect percent for every component of the hot mix and it foud as shown in table 2 and plotted in figure 3

TABLE 2

Sieve opening	%Passing						
	Agg. Size 2	Agg. Size1	Sand (natural)	Sand (crushers)	Mineral Filler	Design Mix	Specs. limits
1.0”	96.01	100	100	100	100	99.1	100
3/4"	78.17	100	100	100	100	95.2	80-100
3/8”	2.3	91.95	98	100	100	75.5	60-80
#4	0	3.4	89.84	99.46	100	48.8	48-65
#8	0	0	74.8	94.51	100	40.4	35-50
#30	0	0	45.1	52.32	100	25.6	19-36
#50	0	0	30.5	13.93	100	18.3	13-23
#100	0	0	17.1	1.06	96.84	11.5	7-15
#200	0	0	6.36	0.33	80.4	5.6	3-8
% mix ratio	25	20	15	37	3	100	

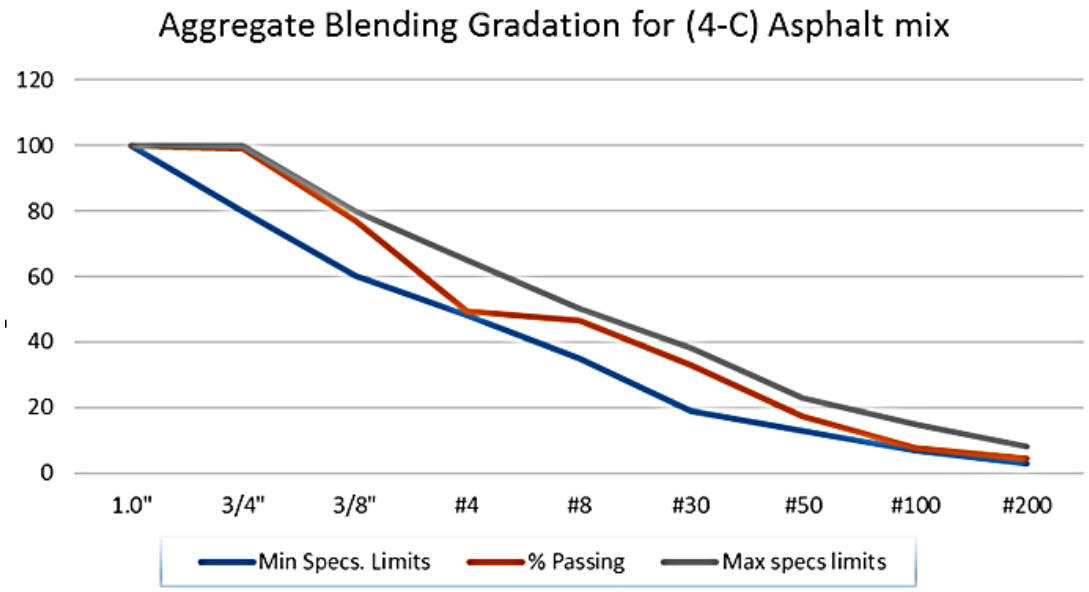

Figure 3

III. RESULTS & DISCUSSION

3.1 Effect of both Residuals and asphalt content on Mixes stability:

Figure 4 shows the stability of the conventional mix and the residuals mixes with various concentrations. The Main behavior of residual mixes stability of the three water treatment plants is generally having the same trend. It’s noticed that the stability has increased from 1121 kg for conventional mix to 1288, 1660 and 1709 Kg after adding 5, 10 and 15% of Galia’s Residuals from sand. The stability increased by 14, 48 and 52% after adding Galia’s plant Residuals by 5, 10 and 15% respectively as shown in figure 4. It is noticed that the stability has increased from 1121 kg for conventional mix to 1338, 1638 and 1724 Kg after adding 5, 10 and 15% of Mansoura’s plant Residuals from sand so the stability increased by 19, 46 and 53% after adding Mansoura’s plant Residuals as shown in figure 4. It’s noticed that the stability has increased from 1121 kg for conventional mix to 1301, 1436 and 1578 Kg after adding 5, 10 and 15% of Meit’s Fares Residuals from sand so the stability increased by 16, 28 and 41% after adding Meit’s Fares plant Residuals 5, 10 and 15%.

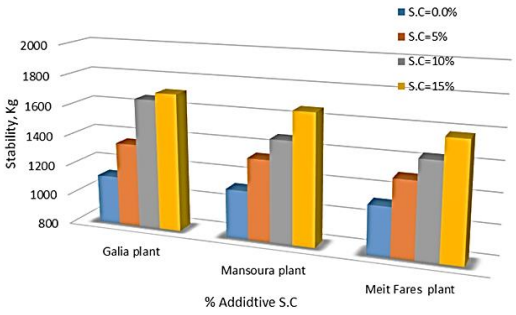

Figure.4 the stability of asphalt mixes

It's observed that stability in asphalt mixes with added Residuals are in specifications limits according to "The Egyptian code for Highways".

It's was noticed that as the turbidity of the source canal increased. The increase in stability may be related to the increase of the turbidity. This increasing in stability for Galia's residual mixes may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.435 and 2.417 ton/m³ so it increased by 3, 2 and 1% after adding Galia's planet Residuals. This increasing in stability may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.444, 2.416 and 2.392 ton/m³so it increased by 2, 1.5 and 0.5l% after adding Mansoura's planet Residuals. This increasing in stability may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.410 and 2.383 ton/m³so it increased by 3, 2 and 1% after adding Meit's Fares planet Residuals.

3.2 Effect of both Residuals and asphalt content on Mixes flow:

Figure 5 shows the flow of the conventional mix versus the residual mixes with various concentrations. The Main behavior of residual mixes flow is generally has the same trend. It's noticed that the flow has decreased from 2.7 mm for conventional mix to 2.4, 2.6 and 2.6 mm after adding 5, 10 and 15% of Galia's Residuals from sand so the flow decreased by 12, 3 and 3% after adding Galia's plant Residuals by 5, 10 and 15% respectively. It is noticed that the flow has decreased from 2.7 mm for conventional mix to 2.4, 2.6 and 2.6 mm after adding 5, 10 and 15% of Mansoura's plant Residuals from sand so the flow decreased by 12, 3 and 3% after adding Mansoura's plant Residuals 5, 10 and 15% respectively. It is noticed that the flow has decreased from 2.7 mm for conventional mix to 2.4, 2.4 and 2.5 mm after adding 5, 10 and 15% of Meit's Fares Residuals from sand so the flow decreased by 12, 12 and 8% after adding Meit's Fares plant Residuals 5, 10 and 15% respectivel

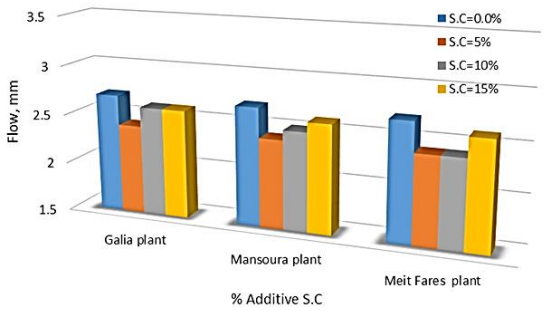

Figure.5 the flow of asphalt mixes

It's observed that flow in asphalt mixes with added Residuals are in specifications limits according to "The Egyptian code for Highways".

This decreasing in flow may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.435 and 2.417 ton/m³. It increased by 3, 2 and 1% after adding Galia's planet Residuals. This decreasing if flow may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.444, 2.416 and 2.392 ton/m³. It increased by 0.02, 0.015 and 0.005l% after adding Mansoura's planet Residuals. This decreasing in flow may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.410 and 2.383 ton/m³. It increased by 3, 2 and 1% after adding Meit's Fares planet Residuals

3.3 Effect of both Residuals and asphalt content on Mixes Density:

Figure 6 shows the bulk density of the conventional mix and the residual mixes with various concentrations. The Main behavior of residual mixes density is generally has the same trend. It is noticed that the density has decreased from 2.345 kg/cm³ for conventional mix to 2.314, 2.303 and 2.284 Kg/cm³ after adding 5, 10 and 15% of Galia's Residuals from sand the density decreased by 1, 2 and 3% after adding Galia's plant Residuals 5, 10 and 15% respectively. It is noticed that the density has decreased from 2.345 kg/cm³ for conventional mix to 2.323, 2.299 and 2.291 Kg after adding 5, 10 and 15% of Mansoura's plant Residuals from sand the density decreased by 1, 2 and 2.3% after adding Mansoura's plant Residuals 5, 10 and 15% respectively. It is noticed that the density has increased from 2.345 kg/cm³ for conventional mix to 2.334, 2.291 and 2.265 Kg/cm³ after adding 5, 10 and 15% of Meit's Fares Residuals from sand the density decreased by 0.4, 2.3 and 3.5% after adding Meit's Fares plant Residuals 5, 10 and 15% respectively.

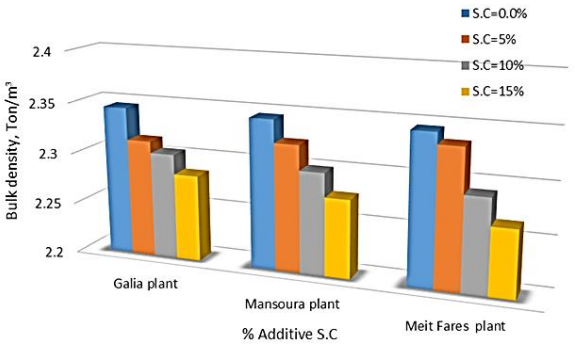

Figure.6 The density of asphalt mixes

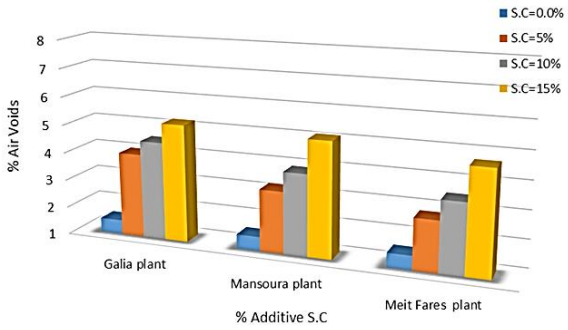

Figure.7 The air voids of asphalt mixes

It's observed that flow in asphalt mixes with added Residuals are in specifications limits according to "The Egyptian code for Highways".

This increasing in density may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.435 and 2.417 ton/m³. It increased by 3, 2 and 1% after adding Galia's planet Residuals. This increasing in density may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.444, 2.416 and 2.392 ton/m³. It increased by 0.02, 0.015 and 0.005l% after adding Mansoura's planet Residuals. This increasing in stability may be due to the closure porosity voids which increase dry density from 2.38 ton/m³ to 2.452, 2.410 and 2.383 ton/m³. It increased by 0.03, 0.02 and 0.01% after adding Meit's Fares planet Residuals

3.4 Effect of both Residuals and asphalt content on Mixes air voids

The Main behavior of residual mixes air voids is generally has the same trend. It's noticed that the air voids has increased from 1.5% for conventional mix to 5.2, 4.5 and 4% after adding 5, 10 and 15% of Galia's Residuals from sand so the air voids increased by 346, 300 and 266% after adding Galia's plant Residuals 5, 10 and 15% respectively. It is noticed that the air voids has increased from 1.5% for conventional mix to 5.1, 3.9 and 3.2% after adding 5, 10 and 15% of Mansoura's plant Residuals from sand so the air voids increased by 340, 260 and 206% after adding Mansoura's plant Residuals 5, 10 and 15% respectively. It is noticed that the air voids has increased from 1.5% for conventional mix to 4.7, 3.5 and 2.8 Kg after adding 5, 10 and 15% of Meit's Fares Residuals from sand so the air voids increased by 480, 233 and 186% after adding Meit's Fares plant Residuals 5, 10 and 15% respectively

It's observed that air voids in asphalt mixes for Galia and Mansoura and were 5.2, 5.1, at 5% Residuals were over specifications and this may be due to the replacement of Residuals instead of filler which for 10% and 15% it was within the specification.

3.5 Effect of both Residuals and asphalt content on Mixes VMA:

Figure 8 shows the stability of the conventional mix and the residual mixes with various concentrations. The Main behavior of residual mixes V.M.A is generally has the same trend. It's noticed that the V.M.A has increased from 12.3% for conventional mix to 13.8, 14.2 and 14.6% after adding 5, 10 and 15% of Galia's Residuals from sand so the V.M.A increased by 12, 13 and 16% after adding Galia's plant Residuals 5, 10 and 15% respectively. It is noticed that the V.M.A has increased from 12.3 kg for conventional mix to 14.2, 14.4 and 14.7% after adding 5, 10 and 15% of Mansoura's plant Residuals from sand so the V.M.A increased by 15, 17 and 20% after adding Mansoura's plant Residuals 5, 10 and 15% respectively. It is noticed that the V.M.A has increased from 12.3 kg for conventional mix to 14.6, 14.7 and 14.9% after adding 5, 10 and 15% of Meit's Fares plant Residuals from sand so the V.M.A increased by 19, 20 and 21% after adding Meit's Fares plant Residuals 5, 10 and 15% respectively.

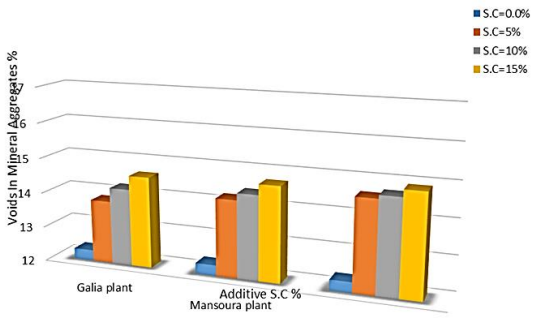

Figure.8 The V.M.A. for asphalt mixes

It's observed that V.M.A in asphalt mixes with added Residuals are in specifications limits according to "The Egyptian code for Highways".

3.6 Effect of both Residuals and asphalt content on Mixes V.F.A:

Figure 9 shows the V.F.A of the conventional mix and the residual mixes with various concentrations. The Main behavior of residual mixes V.F.A is generally having the same trend. It's noticed that the V.F.A has decreased from 88% for conventional mix to 62.5, 68.1 and 72.5% after adding 5, 10 and 15% of Galia's Residuals from sand so the V.F.A decreased by 29, 23 and 18% after adding Galia's plant Residuals 5, 10 and 15% respectively. It is noticed that the V.F.A has decreased from 88% for conventional mix to 58.6, 66.8 and 77.9% after adding 5, 10 and 15% of Mansoura's Residuals from sand so the V.F.A decreased by 33, 24 and 12% after adding Mansoura's plant Residuals 5, 10 and 15% respectively. It is noticed that the V.F.A has decreased from 88% for conventional mix to 53.9, 78.3 and 81% after adding 5, 10 and 15% of Meit's Fares Residuals from sand so the V.F.A decreased by 39, 11 and 8% after adding Mansoura's plant Residuals 5, 10 and 15% respectively

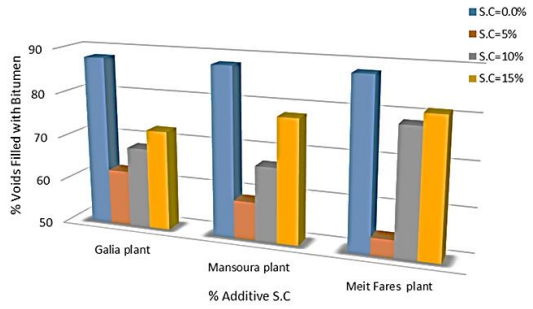

Figure.9 The V.F.A. for asphalt mixes

It's observed that V.F.A in asphalt mixes with added Residuals are in specifications limits according to "The Egyptian code for Highways".

IV. Conclusion

This research achieve the use of water treatment residuals in asphalt mix which solve the problem of solid waste disposal produced from water treatment industry, That is a significant environmental issue. As the residual percentage increased the asphalt mix.

Increased, also it is noticed as the stability of the source canal increased that the stability increased. It was noticed that the residual percentage in the asphalt mix is directly proportionally to the stability, air voids and V.M.A and inversely proportionally to the flow, bulk density and V.F.A. All the properties are in the specification limits according to "The Egyptian code for Highways.

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