

## EFFECT OF USING WASTE IRON POWDER AS FILLER ON ASPHALT MIXTURE PROPERTIES

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### ABSTRACT

The reuse of industrial waste in all areas of life, including the construction of roads, has recently become popular. The type of waste used in the roads may vary between plastic waste, chemical waste, iron manufacturing waste (steel slag or iron fillings), or reclaimed asphalt pavements... etc. This research is performed to study the effect of using Iron Waste Powder (IWP) in asphalt mixtures as a portion of mineral filler (limestone dust). Four models with different (IWP) percentages were examined by Marshall Test to determine the effect of this additive on the asphalt mixture properties and these percentages of (IWP) contents, namely; 25%, 50%, 75% and 100% as a replacement of the weight of the mineral filler. Test results show that 50% of (IWP) will improve stability and flow, where the stability are increased about 24% and the flow also increased about 18% compared to the reference asphalt mixture.

**KEYWORDS:** Asphalt mixture, Iron filings, Iron waste powder, Marshall Stability and Flow Test.

### 1. INTRODUCTION

It is no secret to the world the big problem caused by industrial waste of various kinds and forms and its chemical constituents on the environment and public health and its impact that, which led to the emergence of a tendency by the scientific authorities to reduce the impact of these wastes through the reuse of these industrial wastes. The study of the impact of the use of industrial wastes of all kinds on construction fields in general and on roads in particular has been popularized recently. These wastes have varied between plastic or organic waste or iron and other waste and even the combination of more than one type.

The accumulated waste in the long term destroyed the near ecosystem, as shown by many studies that showed the effect of disposal of stone waste leading to a deterioration of the health of the residents of the region [1].

Karashin & Terzi (2000) studies the related to the potential use of marble waste in the flexible pavement, here, marble dust was used as filler to study behavior in HMA, 75/100 grade penetration binder was used as adhesive. The mix was tested for Marshall Stability and dynamic plastic deformation. Stability value of sample containing marble waste as filler was similar to that of control sample containing conventional filler; however, higher plastic deformation was observed in a mix containing

marble dust as filler. The overall performance was suitable enough for low volume roads [2].

In European countries Recycling of waste material like blast furnace slag, power plant residues, reclaimed asphalt pavement (RAP), reclaimed concrete aggregates (RCA) in pavement construction is also practiced [3].

The recycling of asphalt pavement history dates back to the early 1900s. The most important primary factors that influence the use of (RAP) in asphalt pavements are economic savings and environmental benefits which were adopted at these days [4]. RAP is a useful alternative to virgin materials because it reduces the use of virgin aggregate and the amount of virgin asphalt binder required in the production of hot mix asphalt (HMA) [5].

Izaks et al. (2015) design three mixtures, the researcher use two combinations of two different RAP sources and local dolomite aggregates. The RAP binder had significantly aged having penetration of around 38mm, softening point of 56°C and Fraass breaking point temperature of -10°C. RAP was added at rates 30% and 50% for each RAP source. All mixtures meet the minimum stability criteria of 10 kN for medium and high traffic intensity roads, and satisfy the air voids in mineral aggregate (VMA) and air voids filled with asphalt (VFA) requirements. At the same time all mixtures meet Marshall Flow criteria of 1-4mm. [6]

Other researchers investigated the influence of adding styrene-butadiene-styrene (SBS) polymer with 3, 4 and 5% by weight of asphalt on asphalt mixture containing 30% reclaimed asphalt pavement by weight of mixture. However, Marshall stability results shows increased by 26.4% while Marshall flow decreased by 10.5% when adding 5% of SBS polymer to asphalt mixture. [7]

The use the Stabilized Bottom Ashes from municipal waste incinerators and Electric Arc Furnace Steel Slags as fillers in asphalt mixture and in certain conditions the investigated fillers increase the performance of the corresponding mixtures in comparison to standard (calcareous) filler. [8]

As the evaluation of the behavior of mineral fillers addition in asphalt mastic fillers such as stone dust (SD), brick dust (BD) and fly ash Class F (FA) and conclude that the impact of the addition of 7% fly ash Class F showed improvement in properties of asphalt mix, also reduce the cost, improved performance, and good environmental impacts. [9]

Arabani and Mirabdolazimi (2011) have shown that employing desirable waste materials in hot mix asphalt (HMAs) and in some special cases, such as the addition of blast furnace slag and metallic materials of waste electronic improves their dynamic properties noticeably. [10]

The comparison of the use of two different types of waste metal fibers (recovered from old tires and shavings from machining industry) and two other types of commercial particles (steel wool and steel grit) regarding their effect on volumetric, mechanical and healing properties of asphalt mixes. Results showed that, with a proper design, the improvement in such

properties by using waste metals is comparable to that obtained by using commercial particles. [11,12]

## 2. AIM OF THE STUDY

Despite the widespread use of iron waste or byproducts of all kinds such as blast furnace slag, blast furnace flue dust and iron filings in the asphalt mix at present in various countries of the developed world. In this research the impact on the properties and performance of asphalt mixture of the use of industrial iron waste as a portion of aggregate or mineral fillers will be investigated.

The main aims of the study are:

1. To investigate the impact of using Iron Waste Powder (IWP) as portion replacement of mineral filler on the properties of asphalt mixture such as percentage of air voids, stability, and flow.
2. To improve the properties of asphalt
3. Reduce the impact of industrial iron waste on the environment.
4. Reduce the use of natural sources of materials.

## 3. MATERIALS

### 3.1 Aggregate

In this study, materials such as sand, gravel, and crushed stone has been used from HGG company in Grsheen Suhila for asphalt products. Table 1 shows the aggregate gradation test using Iraqi gradation of asphalt mixture according to the Iraqi Specification (SORB) for binder course [13]. Specific gravity for coarse aggregate was 2.645 gm/cm<sup>3</sup> and it's with the Iraqi specification limitations, and this value depend on the value of the bulk specific gravity (apparent specific gravity) of the coarse aggregate.

**Table (1): Aggregate gradation.**

Sieve		Mid passing %	Iraqi specification limits %	Specification
mm	imperial			
25	1	100	100	ASTM C136-06
19	¾	95	90-100	
12.5	½	83	76-90	
9.5	3/8	68	56-80	
4.75	No. 4	50	35-65	
2.36	No. 8	36	23-49	
0.3	No. 50	12	5-19	
0.075	No. 200	6	3-9	

### 3.2 Asphalt Cement

Bitumen is the material in mix that holds the aggregate minerals together and gives the mix a

flexible property. Bitumen could be produced naturally or chemically from petroleum's. The Bitumen used in this study was obtained from

HGG company plant Iraq-Erbil. Figure 1 shows the penetration test of bitumen and the standard

laboratory test results for asphalt cement are presented in table 2.



**Fig. (1):** Penetration test.

**Table (2):** The results of tests performed on asphalt binder (AC 40-50).

Test	Unites	Values	Specification Limits *	Specification
Penetration (25°C)	0.1 mm	48.9	40-50	ASTM D5-06
Ductility (25°C)	cm	160	100 Min.	ASTM D113-07
Penetration after RTFO (25°C)	%	31.8	55 Min.	ASTM D5
Ductility after RTFO (25°C)	cm	82	25 Min.	ASTM D113
Specify gravity of asphalt binder (25°C)	gm/cm <sup>3</sup>	1.03	-	ASTM D70
Flash point	°C	300	232 Min.	ASTM D5-09
Softening point	°C	51.5	52-60	ASTM D36-09
Specify gravity of aggregate	gm/cm <sup>3</sup>	2.645	2.6-2.7	ASTM C127&128-12

\* according to SORB [13]

### 3.3 Mineral Fillers

#### 3.3.1 Filler

The important of mineral filler in asphalt mixtures are they fill voids in paving mix and improve the cohesion of asphalt binder and it may consist of limestone or other stone dust, Portland cement, hydrated lime or other inert non-plastic mineral matter from approved sources. Mineral Fillers should be thoroughly dry and free from lumps. As for our study, using the dust from the gravel and limestone as filler for gravel mix in asphalt mixture design.

#### 3.3.2 Iron Waste Powder (IWP):

To understand the effect of filler type on the properties of asphalt mixture the iron waste powder (IWP) will be used as replacement of mineral filler and will be compensated as a percentage of the weight of the previous material (mineral filler) as 25%, 50%, 75%, and 100%.

## 4. SPECIMEN PREPARATION

### 4.1 Calculate of optimum asphalt content (OAC)

In this research the test specimens of 4 in. (102 mm) diameter and 2.5 in (64 mm) height are prepared according to ASTM Designation D1559-89 [14] by a specified procedure of Hot Mixture Asphalt (HMA) (figure 2), mixing, and compacting the mixture of asphalt and aggregates which is then subjected to a stability flow test and a density-voids analysis. Results of Marshall Test can be seen in figure 3. Test specimens for the Marshall method are prepared for a range of asphalt contents within the prescribed limits. The asphalt content for a specified amount of 4 to 6 percent, mixtures of 4, 4.5, 5, 5.5, and 6 are prepared. At least three specimens are provided for each asphalt content, to facilitate the provision of adequate data, a total minimum of 15 specimens are required. The amount of aggregates required for each specimen is about 1200g. Table 3 shows the properties of the optimum asphalt content (OAC) that will be used for the other specimens which it's computed according to the Asphalt Institute (AI) and National Asphalt Pavement Association (NAPA).



Fig. (2): Prepare Marshall specimens to determine OAC.

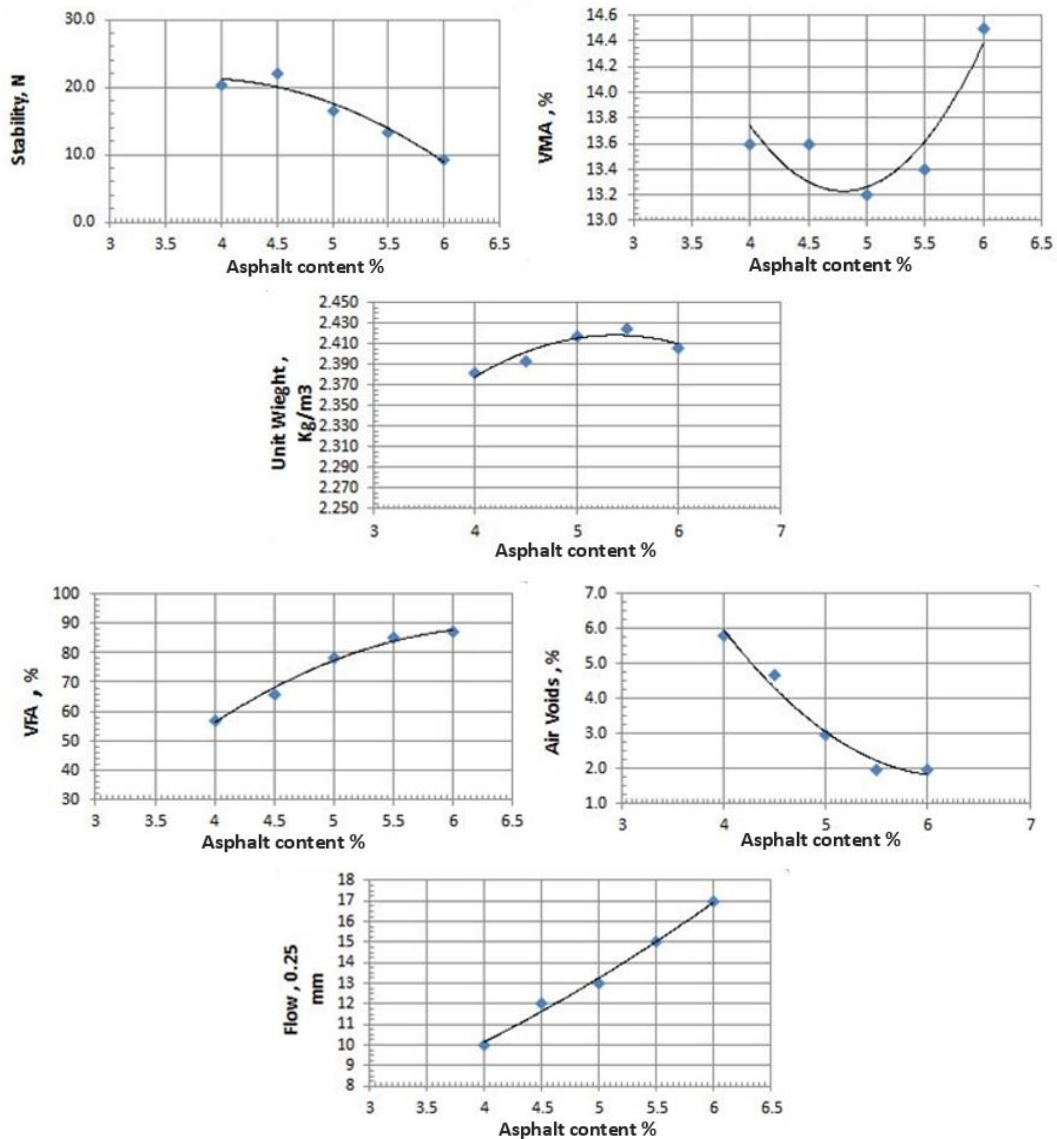


Fig. (3): Marshall Test to obtain the optimum asphalt content.



**Table (3):** Properties of the mixture design with optimum asphalt content.

Properties	Limitations [13]		Mixture design
	Min.	Max.	
Asphalt content% (AC)	4	6	4.70
Bulk specific gravity (Gmb)	-	-	2.41
Max. specific gravity (GMM)	-	-	2.503
Air voids % (Va)	3	5	4
Air voids in mineral aggregate % (VMA)	13	-	13.6
Air voids filled with asphalt % (VFA)	65	85	74
Stability (kN)	7	-	18.5
Flow (0.25mm)	8	16	12.7
Absorbed asphalt % (Pba)	-	-	0.69
Effective asphalt content % (pbe)	-	-	4.01

#### 4.2 Using iron filing to find the Optimum Iron Filings Content

In this stage IWP was used as mineral filler instead of the existing one and was compensated as a percentage of the weight as listed in table 4. The Optimum Asphalt Content (OAC) mixture

has been used to find the optimum IWP percent by using various contents were prepared and conducted according to ASTM Designation D1559-89 Marshall Mixture design method as illustrated in figure 4.

**Table (4):** Prepare the specimens with different ratios of iron waste powder.

Specimen type	Percent of Iron waste powder	Percent of fillers material
#1*	0%	100%
#2	25%	75%
#3	50%	50%
#4	75%	25%
#5	100%	0%

#1\*: Specimen with optimum binder content which it will be used as a reference.



**Fig. (4):** Marshall Test preparation specimens with IWP.

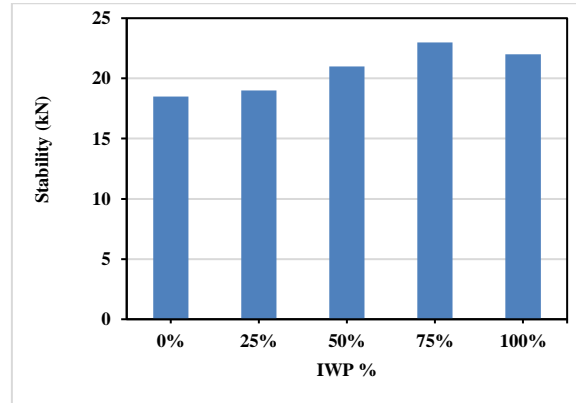
### 5. RESULTS AND DISCUSSION

Marshall Stability and flow tests were conducted on compacted specimens at Optimum Asphalt Content (OAC) and various IWP contents. Figures 5, 6, 7, 8, 9, and 10 show the properties of Marshall Test results for different portions of IWP.

Stability is defined as the capability of a mixture to hold the particles loading, based on the results of test it can be noticed that the stability increases by adding IWP to asphalt mixtures for most specimens as shown in figure 5. Specimen #4 with 75% IWP + 25% of lime stone dust records the highest stability value of 23 KN. The results for 75% of IWP value

increasing the stability by 24% compared with the reference mix, while the improvement in stability for 25%, 50% and 100% of IWP were 3%, 14% and 19% respectively. The improvement in stability property leads to an

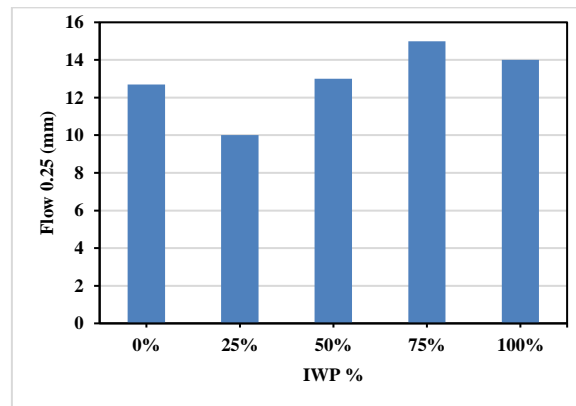
improvement in the resistance to shoving and rutting of the asphalt mixture as it will reduce deformations and thus reduce cracks resulting from these deformations.



**Fig. (5):** Marshall Test Stability results.

Figure 6 shows the results of Flow for Marshall Test which represents the deformation of the samples under loads. In general, there is an increasing in the flow value with increasing of IWP percentage where the mixture with 75% of IWP achieve the highest flow value with

15mm which its 18% higher than the reference mix, also mixtures with 50% and 100% of IWP increasing the flow about 2% and 10% respectively. While for 25% of IWP there was a reduction in flow value by 21% compared to the reference



**Fig. (6):** Marshall Test Flow results.

Generally there is an improvement of using IWP on HAM properties in particular on

stability and flow and table (5) illustrates the percent of change in stability and flow values.

**Table (5):** Percentage of change for stability and flow values with using Iron Waste Powder

No.	Stability (kN)	Change percent	Flow (0.25mm)	Change percent
#1*	18.5		12.7	
#2	19	3%	10	-21%
#3	21	14%	13	2%
#4	23	24%	15	18%
#5	22	19%	14	10%

#1\*: Reference Mix.

Effect of IWP percentage on Air voids percent in asphalt mixture results shown in

figure 7, and it shows that the results of using 50%, 75% and 100% of IWP will achieve the

requirements of Iraqi Specifications by keeping the percentage of air voids within the limits

permitted in the standard with 3%, 3% and 4% respectively for each of IWP proportions used.

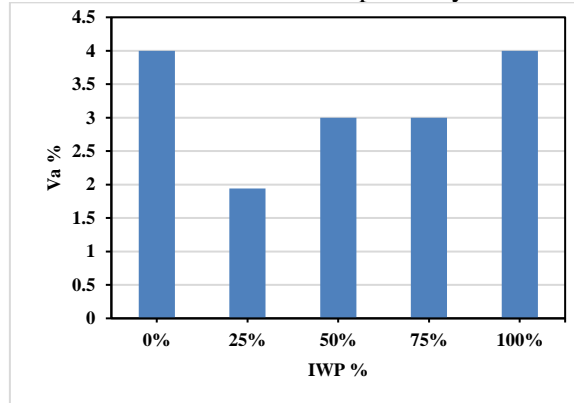


Fig. (7): Marshall Test results of air voids.

Figure 8 present the effect of IWP percentage on the results of air voids filled with asphalt and it shows a variation in the results compared to the reference mixture. Generally all results are in the range of Iraqi specifications limits except for

25% of IWP which it's out of limitations and this may due to the effective asphalt content in this sample high, which led to filling the spaces between aggregate particles with binder.

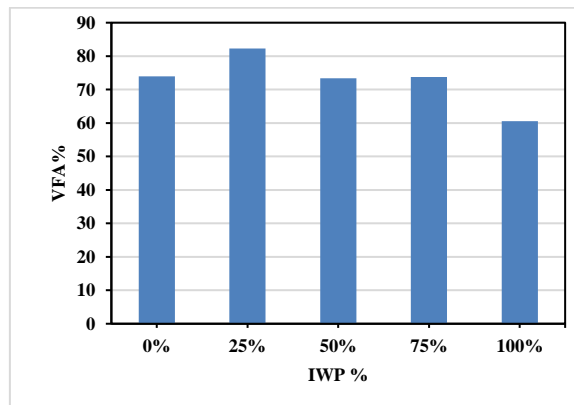


Fig. (8): Marshall Test results of air voids filled with asphalt.

Air voids in mineral aggregates results shows decreasing with adding IWP compared to the

reference mix (see figure 9) this reduction ranged between 11% and 23%.

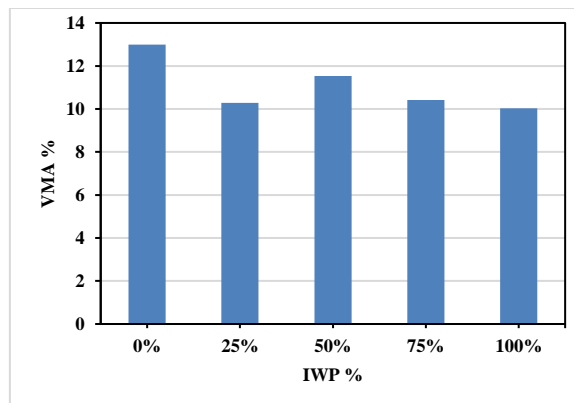


Fig. (9): Marshall Test results of air voids in mineral aggregate.

The results of Marshall Test of effective asphalt content (Pbe) and its affected with the IWP percentage presents in Figure 10, which shows a decrease of effective asphalt content as

the percentage of IWP increases, which means decrease in the amount of asphalt covering the surface of the aggregate and increasing the absorbed asphalt.

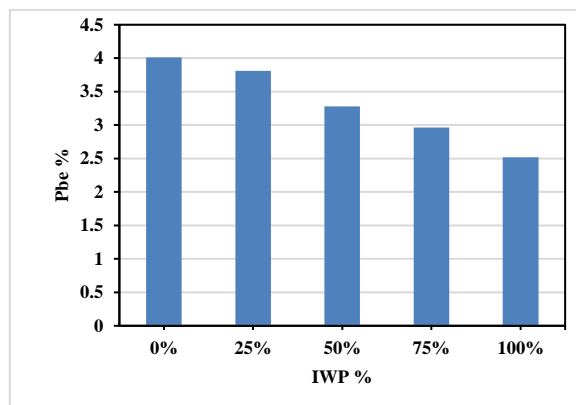


Fig. (10): Marshall Test results of Effective asphalt content.

From the final results of Marshall Test, it can be concluded that the optimum content of IWP based on the results of Marshall Test are 50%, 75% and 100%, this is due to the results of stability, flow, and air voids which are acceptable by Iraqi specifications.

## 6. CONCLUSION

Based on Marshall Stability and Flow Test results for asphalt mixtures with Iron Waste Powder compared with reference asphalt mixture, the following conclusions can be drawn:

1. The optimum content of Iron Waste Powder that can be added to the asphalt mixture to is 50% of the weight of the filler material.
2. Stability improved with using 25%, 50%, 75%, and 100% of Iron Waste Powder by 3%, 14%, 24%, and 19% higher than the asphalt mixture reference.
3. Flow improved of asphalt mixture with 50%, 75%, and 100% of Iron waste Powder by 2%, 18%, and 10% higher than the reference mixture.
4. Air voids percent was affected with using of Iron Waste Powder in asphalt mixes by 3% for IWP of 50% and 75%, while 4% for IWP of 100%.
5. Effective asphalt content decreases with increasing iron content in the asphalt mixture and that reduce the amount of binder forms a bonding film on the aggregate surfaces.

6. The value of air voids in mineral aggregate shows a reduction with using Iron Waste Powder (IWP).

7. Due to the results obtained, it is possible to recommend the use of Iron Waste Powder (IWP) as a percentage or 100% of the filler in the asphalt mixture, as it will reduce the negative impact of these wastes on the environment in addition to the improvement in the properties of the asphalt mixture.

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