



## EFFECT OF WASTE FOUNDRY SAND ON INDIRECT TENSILE STRENGTH OF ASPHALT MIXTURE

Dr. Zainab Ahmed Abdulsattar, \*Eman Abdulhassan Mohammed

- 1) Asst. Prof. Highway and Transportation Department, Mustansiriayah University, Baghdad, Iraq.
- 2) Asst. lec Highway and Transportation Department, Mustansiriayah University, Baghdad, Iraq.

**Abstract:** Laboratory study for the use of recycled foundry sand to improve the performance of asphalt concrete mixture by replacement fine aggregate by waste foundry sand substitute for normal sand was conducted. The experimental work conducted for (4) different proportions (5, 15, 20 and 25)% as fine aggregate . (35) samples was prepared to examine the Marshall stability and flow and moisture damage for asphalt mixture. The obtained results indicate an increase of strength (IDT) for all mixtures than control mixture and higher resist to moisture damage with mixture has(FS (#50).The results showed improvement in behavior in terms of workability and durability and resistance.

**Key Words:** Hot-mix asphalt; Foundry sand.

### تأثير رمل الصب المعاد تدويره على قوة الشد غير المباشر للخلطة الإسفلتية

**الخلاصة:** أجريت دراسة مختبرية لاستخدام رمل الصب المعاد تدويره لتحسين أداء الخلطة الإسفلتية عن طريق استبدال الركام الناعم بواسطة رمل الصب المعاد تدويره. الفحوصات المختبرية التي اجريت ل (4) نسب مختلفة (5، 15، 20 و 25)% ركام ناعم. اشارت النتائج إلى زيادة (IDT) لجميع الخلطات وان أعلى مقاومة لتلف الرطوبة مع الخلطة المكونة من (FS (#50).

## 1. Introduction

Recycling and reuse, environmentally safe disposal of any last remaining material. Increasing recycling and Industrial use of secondary products, such as foundry sand consumer of iron, steel and aluminum foundries may be one of the four priorities in challenging the preservation of resources and the Environmental Protection Agency. The use of foundry sand in various construction engineering applications can solve many environmental problems. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual and dust. Foundry sand can be used in pavement to improve its strength and other durability factors. The Environmental Protection Agency has found that the spent foundry

\*[imalnalghalbi@gmail.com](mailto:imalnalghalbi@gmail.com)

sand produced by the iron and steel foundries and aluminum, which are Rarely dangerous. EPA supports the use of foundry sand consumer of these species in the foundry [5].

The following applications:

- As part of the replacement of fine aggregate in asphalt mixtures.
- As part of the replacement of fine aggregate in Portland reinforced concrete.
- The source material for the manufacture of Portland cement. And
- The sand used in mixing mortar construction

In addition, the use of foundry sand from foundry, iron, steel and aluminum in flow able fill, road Dams, road base and soil manufacturers, agricultural adjustments, and similar uses might be appropriate. Depending on the location and composition of sand for these applications, and characterization of sand and evaluate specific locations is advised before use.[1]

The study will lead to possible innovative utilization of foundry sand in construction of roads apart from its present use in land fill application. The use of waste foundry sand, if could be feasible, will not only provide for its better utilization but also will help in conserving the precious natural resource of natural sand.

However. A rate of 5.5% cement added for foundry-modified subbase and results were encouraging and satisfied [2]. Another findings showed that inclusion of 5-15% in base-subbase did not alter neither the OMC nor MDD. However, the resilient modulus results were much less that of the referenced base mixtures and further investigation on performance of modified base-subbase materials was suggested [3]. In CIPR mixtures, foundry sand was found of high potential characteristics to surrogate the natural aggregates in the CIPR mixture despite the fact that less improvement has been gained in strength, stiffness and rutting resistance of the foamed asphalt mixture with foundry than the bottom ash [4].

## 2. Experimental Study and Testing Program

The experimental program was divided into two phases. In the first phase, control samples Nibaee aggregate. In the second phase, samples with FS (5% instead of sieve No.200 , 15% instead of sieve No.8 ,20% instead of sieve No.4and 25% instead of sieve No.50) .

phase 1: control sample “FS = 0%” The mix design was carried out using 5.0% asphalt contents, which is the optimum bitumen content for control specimen. All mixes were prepared according to (SCRB ,2003)standard assuming heavy traffic.

phase2: sample with five different percentages of FS (5%,15%, 20%,and 25%) were blended with VA.

### 2.1. Material

To obtain laboratory specimens with the same engineering characteristics as those used in pavement. The materials tested in this study are locally available in Iraq and used in road

working. The aggregates used, crushed aggregate brought from the hot mix plant of Al-Nibae quarry at Al-Taji.

### 2.1.1. Asphalt cement

The binder used in this study is petroleum asphalt cement brought from Daurah refinery. The physical properties of the asphalt cement are presented in Table (1).

### 2.1.2. Coarse aggregate

The coarse aggregate (crushed) is brought from the hot mix plant at Al-Taji. It is originally brought from Al-Nibae quarry. It consists of hard, strong, durable pieces, free of coherent coatings. The sizes of coarse aggregate range between 3/4 in. (19.0 mm) and No.4 sieve (4.75 mm) according to SCRB specification (2003).

### 2.1.3. Fine aggregate

Two types of fine aggregate are used in this study. These are crushed and river sand aggregate. They are the fine part of the aggregate mentioned above. The ranges of fine aggregates are between passing 4.75mm (No.4) sieve and retained on 0.075mm (No.200) sieve. The physical properties and the chemical composition of the fine aggregate are shown in Tables (2) and (3) respectively.

### 2.1.4. Mineral fill

One type of mineral filler is used: ordinary portland cement (from Kubaisa factory). It is thoroughly dry and free from lumps or aggregations of fine particles. The State Corporation for Roads & Bridges in Iraq (SCRB, 2003) established standard specifications for binder course. The gradation used in this study is shown in “Table (1)”.

Table (1): Gradation of the Aggregate for binder Course (SCRB, 2003).

| Sieve Size | Sieve Opening (mm) | Percentage Passing by Weight of total Aggregate |  |
|------------|--------------------|---|--|
|            |                    | Specification Limit (S.C.R.B)                   | Base Course<br>Selected gradation of Aggregate |
| 1"         | 25.0               | 100   | 100  |
| 3/4"       | 19.0               | 90-100  | 95   |
| 1/2"       | 12.5               | 70-90   | 80   |
| 3/8"       | 9.5                | 56-80   | 68   |
| No.4       | 4.75               | 35-65   | 48   |
| No.8       | 0.425              | 23-49   | 33   |
| No.50      | 0.3                | 5-19  | 8  |
| No.200     | 0.075              | 3-9   | 3  |

### 2.1.5. Foundry sand (FS)

The foundry sand is normally of a higher quality than natural sands used in fill construction sites



Plate (1): Foundry Sand Used in this Study.

“ Table (2)” shows the results for bulk density, moisture content, specific gravity, dry density; optimum moisture content and permeability...etc. measured using the applicable ASTM standard.

Table (2): Typical Properties of Foundry Sand.

| Design Parameter                                  | Foundry Sand Performance |
|---|--------------------------|
| Specific Gravity                                  | 2.63                     |
| Bulk Relative Density, $\text{kN/m}^3$            | 19.37                    |
| Standard Proctor Max Dry Density, $\text{kN/m}^3$ | 17.3                     |
| Optimum Moisture Content, %                       | 12                       |
| Hydraulic Conductivity (cm/sec)                   | 10-7                     |
| Plastic Index                                     | NP to 12                 |
| Internal friction angle (drained)                 | 37                       |
| Cohesion intercept (drained), $\text{kN/m}^2$     | 0                        |

Since foundry sand has nearly all the properties of natural or manufactured sands, it can normally be used as a sand replacement. It can be used directly as a fill material in embankments. It can be used as a sand replacement in hot mix asphalt .It can also be blended with either coarse or fine aggregates and used as a road base or sub base material (FHWA, 2004).

## **2.2. Marshall Method of Mix Design**

Bruce Marshall formulated the concepts of the Marshall method of designing paving mixtures, and its procedures have been standardized by the American Society for Testing and Materials (ASTM D1559)(1989).

Marshall Method is applicable to design hot-mix asphalt mixtures using penetration or viscosity grade asphalt and containing aggregate with maximum sizes of 25mm or less. It includes four steps (mix properties, mixing procedure, preparation of Marshall Specimens and determining Marshall Properties).

The Marshall properties studied in the current study include Marshall Stability, Marshall Flow, bulk density, percent of voids in total mix (VTM), and percent of voids filled with asphalt (VFA). The optimum asphalt content selected for design is essentially a compromise value, which meets specified requirements for stability, flow, and voids content (VTM and VFA) of asphalt mixture.

The steps of Marshall Method are the same for the original and modified mixes except mixing procedure for the asphalt, which is different for the modified asphalt.

## **2.3. Indirect Test and Moisture Susceptibility**

Indirect tensile, and TSR tests are not listed by SCRB specifications (2003), but these tests are the major test in ASTM and AASHTO specifications .

The tensile strength of compacted asphalt specimens is typically determined by the indirect tensile strength test, which is determined according to the method described in ASTM D4123 (1989). The specimens are prepared in the same procedure given in the article (3.3.2) for the Marshall Mix design method. The prepared specimens are left to cool at room temperature for 24 hours and then placed in a water bath maintained at the test temperature for 30 minutes in order to bring them to the specified test temperature. To accomplish indirect tensile test, the specimens are removed from water bath and immediately placed into the loading apparatus. The compressive load is applied to two opposite loading strips of 12.7mm wide and 63.5mm long made of steel to distribute the load and maintain a constant loading area. Each strip is curved at the interface with the specimen and has a radius equal to that of the specimen. The two loading strips are kept parallel to and centered on vertical diametrical plane. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane that ultimately leads to the specimens' failure by splitting along the vertical diameter. The compressive load is applied at a constant rate of 2inch/min. (50.8mm/min) and the ultimate load at failure is recorded.

Moisture damage in bituminous mixes refers to the loss of serviceability due to the presence of moisture. The extent of moisture damage is called the moisture susceptibility. The ITS test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixture. Tensile strength ratio (TSR) is a measure of water sensitivity. It is

the ratio of the tensile strength of water conditioned specimen, (ITS wet, 60°C, and 24 h) to the tensile strength of unconditioned specimen (ITS dry) which is expressed as a percentage. The acceptable range of TSR limited by AASHTO-T283 (TSR ≥ 80). A higher TSR value typically indicates that the mixture will perform well with a good resistance to moisture damage. The lesser will be the strength reduction by the water soaking condition, or the more water-resistant it will be.

### 3. Effect of Foundry Sand on Indirect Tensile Strength Induced Moisture Damage

The static indirect tensile strength of a specimen is determined using the procedure outlined in ASTM D 6931. A loading rate of 51mm/minute is adopted. Tensile failure occurs in the sample rather than the compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The compressive load indirectly creates a tensile load in the horizontal direction of the sample.

The peak load is recorded and it is divided by appropriate geometrical factors to obtain the split tensile strength using the following equation:

$$IDT = 2000P / \pi t D \quad (1)$$

“Where”

IDT = indirect tensile strength, kPa

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

And moisture sensitivity was evaluated as follows:

$$TSR = (IDT_w / IDT_d) * 100 \quad (2)$$

“where”

TSR = the tensile strength ratio (%),

IDT<sub>w</sub> = tensile strength of five conditioned (wet) specimens (MPa) and ;

IDT<sub>d</sub> = tensile strength of five unconditioned (dry) specimens (MPa).

Table (3) IDT Values

| Material type | IDT(N)           | IDT(N)          | TSR (%) |
|---------------|------------------|-----------------|---------|
|               | Uncondition(dry) | condition (wet) |         |
| Nibaee        | 300              | 193             | 64      |
| FS(#4.0)      | 526              | 384             | 73      |
| FS(#8.0)      | 381              | 302             | 80      |
| FS(#50)       | 472              | 383             | 81      |
| FS(#200)      | 478              | 248             | 52      |

\*TSR ≥ 80% is required by specifications for HMA .

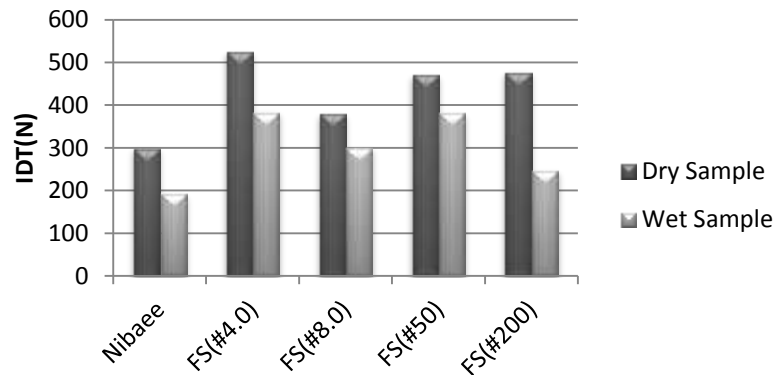


Figure (1) Effect of Foundry Sand on IDT.

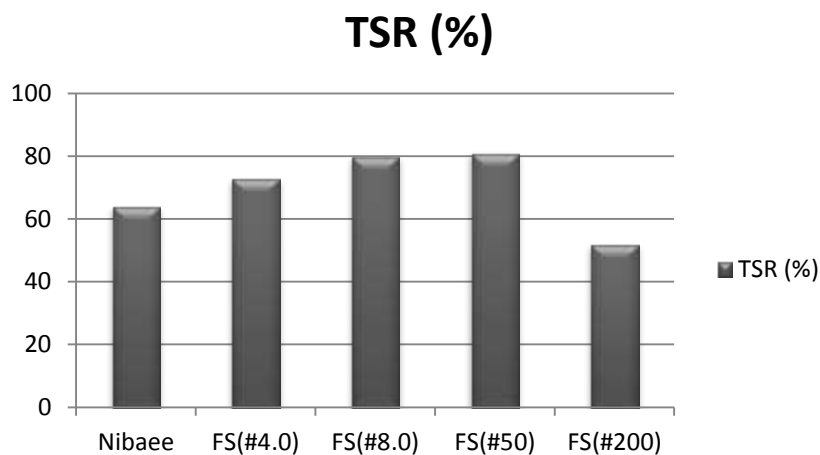


Figure (2) Effect of Foundry Sand on TSR.

The indirect tensile strength results of FS mixtures at various percentages both for conditioned and unconditioned samples are given in Table (6). It is evident that all the FS mixtures showed higher tensile strength than the control mixture.

This is because of the improved stiffness of stabilized mixture than the control mixture. The presence of additives in the bituminous mixture strengthens the bonding between the aggregate provided by the binder and as a result, the mixtures had the highest stiffness. The results also indicate that tensile strength increases with additive content.

The results of the moisture sensitivity tests for samples made with optimum binder content are shown in table (6) and figure TSR values of FS(#8.0,#50) obtained were  $\geq 80\%$ , which is the requirement established in specifications for HMA.

#### 4. Recommendations

The use of FS suitable for commercial projects and engineering, economic and environmental benefits of using these materials make this item to be seriously considered. It is desirable for the criteria to consider in the FS in the environment.

#### 5. Conclusions

1. Using FS in hot asphalt is more efficient and results in higher values for strength. mixture. This may be due to the high strengths provided by FS material.
2. Increase in strength (IDT) with used foundry sand replacement of natural fine aggregate.
3. Use of foundry sand in HMA can save the ferrous and non-ferrous metal industries disposal, cost and produce a 'greener' HMA for construction.
4. Environmental effects from wastes and disposal problems of waste can be reduced through this research. Which consider as an important key in the sustainability of using hot asphalt mixture.
5. The used foundry sand is recommended as a good sustainable material for HMA used in pavement Construction.

#### 6. References

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