A Comparison Study between Porous and Conventional Asphalt Concrete Mixtures

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Abstract. Asphalt concrete is the surface layer, which lay to carry the vehicles above & to transfer the loads effectively without experiencing any significant deformations. This research offers a comparison between porous and conventional asphalt mixtures in physical and service properties. Porous asphalt is an environmentally friendly mix for water runoff management, which can perform similarly to that of other pavements. It can be designed for road construction projects that can carry moderate traffic loads, while the conventional flexible pavement is designed for different projects with higher carrying ability to traffic loads. In this research, a total of 39 asphalt mixture specimens have been used to evaluate the volumetric and service properties for both types of asphalt mixtures; namely, stability, air voids, flow, and indirect tensile strength to reveal the essential differences among them. There is a considerable variation in physical and service properties of both types of asphalt concrete; in general, conventional asphalt concrete tends to have the best physical properties in the lab. The results show that conventional asphalt mixture is more efficient and durable than the porous asphalt but at the same time, porous asphalt mixture can be implemented in heavy rainfall regions regardless of traffic volume.

Keywords: Air voids; conventional asphalt; flow; indirect tensile strength; porous asphalt; stability.

1. Introduction
A good flexible pavement shows an accepted elasticity to traffic loading; it is built up with a relatively thin layer of hot-mix asphalt (HMA) over unrestricted base course laying on a subgrade course [1]. Flexure forces are created from the loading characteristics of a system of layers constructed to protect
the successive underlying layers including the subgrade against compressive shear failure [2]. Surface runoff ultimately will influence the riding quality of pavement surface leading to create a remarkable reduction in the friction coefficient [3].

The porous pavement provides an open graded surface laid on a filter layer of stones in order to drain the surface water effectively [4]. Porous asphalt concrete allows surface water to infiltrate into the sub-base then it can be drained off from there efficiently, while in the conventional asphalt concrete, surface water is prevented from penetrating inside the below layers and it remained at the surface [5]. In the field of roadway sustainability, porous asphalt concrete is considered to be the fastest growing technology which functions by allowing water penetration into the subsurface [6]. The use of porous asphalt concrete is certainly required great efforts and planning than usual asphalt [7].

Hu et al. [7] explained that the technology of porous asphalt has been used in different forms for about fifteen years and continued to evolve until this day.

Hall et al. [8] stated that porous asphalt mixture provides an alternative for conventional asphalt and concrete mixtures in roads pavement design through enhancing the society, promoting the economy and benefiting the environments.

Nakanishi et al. [3] mentioned that porous asphalt is a little coarser than the conventional asphalt but still smooth enough to allow the water to infiltrate the surface to the lower layers so if there is toxins on the surface, they will be swept along with the rainfall and subjected to natural processes that cleanse water.

In this research, the difference between porous and conventional asphalt concrete in physical and service properties has been presented through measuring Marshall Stability, flow, air voids and indirect tensile strength test for both types of asphalt regardless the cost issue.

2. Materials

The materials used in this research are local materials that are widely used in Iraq’s paving processes. These are listed below:

2.1 Bitumen

(40-50) penetration grade of bitumen has been used in this research, which is brought from Al Dora refinery in Baghdad. All the applied tests conducted on the selected bitumen complied with Iraqi specification for Roads and Bridges [9] as shown below in Table 1. These tests were implemented in transportation laboratory of the department civil engineering at Al-Mustaqbal University College, Iraq. (See Figure 1.).

| Property                                      | ASTM method | Unit | Test results | SCRB Specification |
|-----------------------------------------------|-------------|------|--------------|--------------------|
| Penetration at 25 °C, 100 gm, 5 sec           | D5          | 0.1mm| 46           | 40-50              |
| Kinematic Viscosity at 135 °C                 | D2170       | cst  | 382          |                    |
| Absolute Viscosity at 60 °C                   | D-2171      | poise| 4055         | 4000 + 800         |
| Ductility at 25 °C, 5 cm/min                  | D113-99     | cm   | 132          | >100               |
| Flash point (Cleveland open cup)              | D92         | °C   | 240          | Min. 232           |
| Softening Point                               | D36         | °C   | 52           |                    |
| Specific gravity at 25 °C                     | D70         | ---- | 1.04         |                    |
| Retained Penetration at 25°C, 100 gm, 5 sec   | D1754       | %    | 65           | Min. 55%           |
| Ductility at 25 °C, 5 cm/min                  | D1754       | cm   | 79           | Min. 50            |
| Loss in Weight at 163 °C, 5 hours             | D1754       | %    | 0.28         |                    |
2.2 Aggregates

The used aggregate in both porous and conventional asphalt mixtures consist of coarse and fine aggregate. All the aggregate samples were washed thrice-using water to remove debris and dirt. Then they were oven-dried at 100 °C for 24 hrs. Afterwards, the aggregate was sieved to be used in the selected mixture [9].

2.2.1 Coarse aggregate. The coarse aggregate was brought from Al Kut province, Badra type (see Figure 2). The coarse aggregate has been used in:
- Porous asphalt mixtures: the coarse aggregate is sieved to obtain the desired gradation in accordance with the requirements of the National Asphalt Paving Association (NAPA) [8].
- Conventional asphalt mixtures: the coarse aggregate is sieved to achieve the desired gradation according to the requirement of the Iraqi specifications for Roads & Bridges (SCRB) [9].

The gradation of coarse aggregate falls between (19 mm) and (4.75 mm) sieve size. The physical properties of coarse aggregate are shown below in Table 2.

2.2.2 Fine aggregate. The fine aggregate used in this study has been brought from Kerbala quarry (see Figure 3) to be used in:
- Porous asphalt mixtures: sieved to obtain the desired gradation according to the requirements of the National Asphalt Paving Association (NAPA) [8].
- Conventional asphalt mixtures: sieved to obtain the desired gradation according to the requirement of the Iraqi specifications for Roads & Bridges (SCRB) [9].

The gradation of fine aggregate falls between (4.75 mm) and (0.075 mm) sieve size. Physical properties of fine aggregate are shown below in Table 2. Fine aggregate specimens were tested in the same laboratory mentioned earlier (see Figure 4).
Table 2. The physical properties of the aggregate

| Property                  | ASTM Method | Coarse Aggregate | Fine Aggregate |
|---------------------------|-------------|-------------------|----------------|
| Bulk Specific Gravity     | C-127       | 2.612             | 2.672          |
|                           | C-128       |                   |                |
| Apparent Specific Gravity | C-127       | 2.666             | 2.731          |
|                           | C-128       |                   |                |
| % water absorption        | C-127       | 0.8               | 0.65           |
|                           | C-128       |                   |                |
| Abrasion Los Angeles      | C-131       | 18.25%            | -----          |
| Angularity                | D-5821      | 93%               | -----          |

2.3. Mineral aggregates
Ordinary Portland Cement (OPC) was used as mineral filler in this study. The cement’s physical properties are listed in Table 3.
Table 3. The physical properties of cement

| Property                  | Cement | Filler |
|---------------------------|--------|--------|
| Specific Gravity          | 3.14   |        |
| Fineness, Blain, (cm²/gm) | 3200   |        |
| %Passing Sieve No.200     | 95     |        |

2.4. Combined Aggregate Gradation

For porous asphalt mixtures, the applied aggregate gradation was selected according to (NAPA) specification (open-graded) [8], (see Figure 5), while the conventional asphalt mixtures were implemented according to SCRB specification (dense-graded) [9], (see Figure 6) for wearing surface layer as shown below in Table 4. All gradations used are within the middle of specifications.

Table 4. Combined Aggregate gradation

| Standard sieves (mm) | English sieves (inch) | (% Passing by Weight of Total Aggregate + Filler) | Porous Asphalt | Conventional Asphalt |
|----------------------|-----------------------|--------------------------------------------------|----------------|----------------------|
| 19                   | 3/4"                  | 100                                              | 100            | 100                  |
| 12.5                 | 1/2"                  | 93                                               | 85-100         | 95                   |
| 9.5                  | 3/8"                  | 65                                               | 55-75          | 83                   |
| 4.75                 | No.4                  | 18                                               | 10-25          | 59                   |
| 2.36                 | No.8                  | 8                                                | 5-10           | 43                   |
| 0.3                  | No.50                 | -                                                | -              | 13                   |
| 0.075                | No.200                | 3                                                | 2-4            | 7                    |

Figure 5. Aggregate gradation for porous asphalt
3. Sample preparation

3.1. Marshall Test

Once the gradation of aggregate was set in accordance with NAPA specification for porous asphalt mixture and SCRB specification for conventional flexible asphalt mixture, it was used to prepare several specimens at various bitumen contents. These specimens are called Marshall specimens 101.7 mm diameter by 63.5 mm in thickness. Several physical tests were applied on the intended specimens to evaluate the properties of both mixes and the results were compared with Marshall Standards [9] as shown below in Table 5 & 6.

**Table 5. Marshall Standards for Porous asphalt**

| The Lab. Test          | Standards     |
|------------------------|---------------|
| Stability              | > 5 kN        |
| Flow                   | 2 - 6 mm      |
| Air voids              | 10 - 25 %     |
| Permeability           | > 0.01 cm/sec |
| Cantabro loss Unaged   | < 20%         |
| Draindown              | < 0.3%        |

**Table 6. Other Marshall Standard for Conventional asphalt**

| The Lab. Test | Standards |
|---------------|-----------|
| Stability     | > 8 kN    |
| Flow          | 2 - 4 mm  |
| Air voids     | 3 - 5 %   |

The optimum binder content for the designed aggregate gradation has been selected depending on several trial mixes, each mix contains a specific amount of binder, begins with 4% and increasing by 0.5% for each trial until reaching 6%. The optimum binder content for porous asphalt mixtures has been utilized depending on evaluating the following properties [8]:

![Figure 6. Aggregate gradation for conventional asphalt](image)
1. Maximum value of Cantabro abrasion (L.A) test (ASTM D7064 / D7064M-08) [10] as shown in Figure 7.

![Figure 7. Aggregate before and after Los Angeles Abrasion test](image1)

2. The maximum value of binder draindown test (ASTM D6390-90) as shown in Figure 8.

![Figure 8. Draindown Test](image2)

3. The minimum coefficient of Permeability (ASTM PS129-01) [11] as shown in Figure 9.

![Figure 9. Permeability Test](image3)
4. Air voids (ASTM D2041-2041M) [13] as shown in Figure 10.

The optimum binder content for the conventional asphalt mixes has been determined as recommended by Asphalt Institute Manual Serious No. 02. [14], through preforming the following volumetric properties:
1. Maximum value of Marshall Stability Test [15].
2. Maximum value of bulk specific gravity [16].
3. Air voids at 4% [13].

3.2. Indirect Tensile Strength Test
This test has been used to evaluate the tensile strength for asphaltic concrete specimens at (25 °C). The test was implemented according to (ASTM D 6931 – 07) [17] as shown below in Figure 11.
4. Results and Discussion
After conducting the physical tests on both conventional and porous asphalt concrete mixtures the results were presented on drawn curves as shown below in Figures 12 & 13.
According to Fig. 12 and 13, the optimum binder content by weight of total mix for both porous and conventional asphalt mixtures was found to be 5.5% and 5.0% respectively. Indirect tensile strength test was conducted for both porous and conventional asphalt concrete mixtures and the results were represented in a specific chart as shown in Figure 14.

Figure13. Curves of conventional asphalt physical test

Figure14. Chart shows the results of I.T.S
Table 7. General comparisons.

| Porous Asphalt                      | Conventional Asphalt                  |
|-------------------------------------|---------------------------------------|
| Stability (6.8 kN)                  | Stability (9 kN)                       |
| Air content (22%)                   | Air content (4%)                      |
| Flow (5.3 mm)                       | Flow (2.5 mm)                         |
| I.T.S (0.57 MPa) leads to low resistance to tensile stresses. | I.T.S (1.84 MPa) leads to high resistance to tensile stresses. |
| Permeable course (allows infiltration of water to the lower courses) (see Figure 15) | Relatively impermeable (prevent water infiltration to the lower courses) (see Figure 15) |
| Less durable because it requires additional regular maintenance to make sure the pores do not get clogged | High durability asphalt when implemented properly and requires less maintenance |
| Higher binder content               | Lesser binder content                  |
| Can carry a moderate traffic load   | Can carry high traffic loads           |
| Can be implemented in a heavy rainfall region regardless of traffic loading | Can be use in any construction projects under any loading conditions |
| Reduction of water spray of urban roads as shown in Figure 16. | High water sprays on the roads as shown in Figure 17. |

Figure 15. Permeability effect

Figure 16. Porous pavement

Figure 17. Conventional Flexible pavement
5. Conclusion
The following conclusions are drawn:

- Conventional flexible pavement is more durable and loads resistant than porous asphalt. This is due to the high stability, moderate flow value, perfect level of air content, and high resistance to tensile stresses.
- Porous pavement offers moderate stability, relatively high flow value, high air content, and low resistance to tensile stresses. For all the mentioned reasons, porous asphalt can be used in light-duty facilities.
- Porous pavement inhibits surface water flow; hence, achieving traffic claiming for some arterial roads.
- Porous pavement can be used or designed to harvest the water on surface for other uses.
- Porous pavements harness the ability of the earth to mitigate and absorb the surface water and leads to increase in the effective areas, which can be used for development issues.

Nomenclatures

cst Centistoke is the measuring unit of bitumen kinematics
viscosity poise The measuring unit of bitumen absolute viscosity

Abbreviations
NAPA National Asphalt Paving Association
SCRB State Corporation for Roads and Bridges in Iraq
ASTM American Society for Testing and Materials
I.T.S Indirect Tensile Strength

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