Research Note

Analysis of the Strength of Hot in-Place Recycled Asphalt, its Effecting Factors and its Comparison with Conventional Methods

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Abstract

In recent decades, economic development and population growth in the world has led to the expansion of road networks. Therefore, the use of optimum methods for repairing and maintenance of these roads is considered as an important value. Today one of the options in this regard, is the use of asphalt recycling technology. The present study which took place in the summer of 2015 in Iran, Lorestan province, is in line with this target with the goal to compare the recycling of asphalt with the common methods as well as the qualitative assessment of each method. In this study which was based on the analysis of asphalt samples from the Khorramabad - Boroujerd route and samples from Arak-Qom's hot in-place recycling project, 9 laboratory samples were made using recycled asphalt pavements in accordance with the regulations of hot asphalt recycling of Iran. These samples were made using 80% recycled asphalt pavements which were collected from 3 different locations from Lorestan province, as well as 20% raw and new materials. After conducting the quality control tests for asphalt on the 9 samples, one of the 9 samples that had higher technical specifications and was more in accordance with the Arak-Qom's recycling project mix design, was chosen as the optimal sample. The optimum samples test results were analyzed, compared and evaluated with the two projects mentioned above. The results showed that although both methods were in range with the minimum and maximum technical quality specifications, the recycling method had higher quality and technical specifications.

Keywords: Hot in-place recycling (HIR), recycled asphalt pavement (RAP), asphalt stability, asphalt air void.

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1. Introduction

The growing demand on our nation's roadways over that past couple of decades, decreasing budgetary funds, and the need to provide a safe, efficient, and cost effective roadway system has led to a dramatic increase in the need to rehabilitate our existing pavements. The last 25 years has also seen a dramatic growth in asphalt recycling and reclaiming as a technically and environmentally preferred way of rehabilitating the existing pavements around the world. Asphalt recycling and reclaiming meets all of our societal goals of providing safe, efficient roadways, while at the same time drastically reducing both the environmental impact and energy (oil) consumption compared to conventional pavement reconstruction.

In recent years a number of factors have reduced the quality and the life of many of the routes in our country especially in urban areas. Among the important factors in this area are the dramatic rise in costs related to the production and maintenance of roads, the increase of the volume of traffic, the low load capacity of transport routes compared to the traffic passing through, the long time it takes to recover damaged pavements using the usual methods and also the ineffectiveness of traditional treatment methods according to today's needs. With that being said, the necessity of using a new method which is both economical and also technically and environmentally approved is obvious. In this regard the use of recycling technologies in the production of asphalt is an acceptable and optimal solution. It is the reuse of old asphalt material that is damaged and reduced in technical capability or is declining. Asphalt recycling has many advantages and is known as one of the fastest and most efficient methods for rehabilitation and reconstruction of asphalt coatings. Recycling technology is used in most of the branches of science nowadays.

2. Literature Review

Hot in-place recycling of asphalt with the main objective of preserving the nonrenewable natural resources, such as bitumen and the optimum use of them is one of the options put forward in the improvement of road maintenance and is used in many parts of the world. Through this method an optimal solution for the mix design is obtained and the total material cost is minimized while satisfying all the binder requirements [Swamy and Das, 2009].

The recycling technology is actually the reuse of old asphaltic materials that are damaged or their technical capabilities are decreasing. The hot in-place recycling method has many advantages in a way that it is now one of the fastest and optimal methods of rehabilitation and reconstruction of asphalt coatings in the world [Fakhri, 2006]. Despite the wide spread use of this method, little information is available in the literature on the laboratory properties of the materials aspects. For example it has been found that adding a rejuvenator or changing the rejuvenating agents used in the mix can result in the increase of low temperature performance of recycled mixtures and also the reduction of the mixtures stiffness [Hou, Huang and Li, 2007] [Hafeez, Ozer and Al-Qadi, 2014].

In late summer 2004, Hosokawa et al [Hosokawa et al. 2004] carried out a joint research project on hot in-place recycling of porous asphalt concrete over 5km in length in Perugia, Italy. The project had excellent test results concerning air void, grading, permeability, and Marshall Test and Gyratory compaction test. The test results also have confirmed the recycling method would contribute to the reduction of carbon dioxide emission of new resource requirement as well as of repaving cost; thus both direct and external cost will be much reduced by the method.

Oner and Sengoz [Oner and Sengoz, 2015], also stated in their article that the Marshall stability values related to RAP mixtures were higher and that the air void level was within the specification limits

Mallick et al [Mallick, Kandhal and Bradbury, 2008] conducted similar tests in their study, although they used 75% RAP at lower temperatures compared to conventional temperatures, the results showed that it is possible to produce mixes with 75% RAP with similar air voids as virgin mixes.

It is a widely shared view that resulting cost savings by HIR with improved methods for mix design and quality control for recycling are bigger enough when compared with an equivalent amount of resurfacing by the conventional “mill and fill” method [Sorensen and Thomas, 2000]. Therefore it seems it is necessary to compare the quality results of both the recycling method and the conventional methods.

In the present study the data obtained from the HIR method will be analyzed and evaluated and compared with the data collected from the optimal lab samples, in order to review the stability of both asphalts and the factors effecting it. Finally both of the samples will be compared to the usual asphalt paving methods in Iran to understand whether or not the hot recycling method has higher quality specifications compared to the usual methods of paving.

Reclaimed asphalt pavement (RAP) is removed and reprocessed pavement materials containing a mixture of asphalt and aggregates. In different studies carried out, different percentages of RAP have been used. With different percentages, changes in mixture properties were resulted including greater resistance to moisture damage and repeated loading [Huang, Shu and Vukosavljevic, 2011], increased stiffness and indirect tensile strength [Rondon, Urazan and Chavez, 2015] and the increase of the dynamic modulus [Shahadan et al. 2013].

3. Materials and Methods

In the present study three types of recycled asphalt pavement (RAP) were collected from three different locations in the Lorestan province, Iran and were used to make recycled asphalt samples. In total nine samples were made, three from each location according to the Arak-Qom routes recycling mix design. Then the quality control tests of asphalt were conducted on them. Finally the results of the tests were compared with the Arak-Qom recycling project and the Khorramabad-Boroujerds project results.

The recycled asphalt pavements which were used to make the lab samples were collected from the routes listed below:

- Khorramabad-Boroujerd route, Lorestan province
- Khorramabad-Sepiddasht route, Lorestan province
- Aleshtar-Firuzabad route, Lorestan province

The use of processed RAP in hot mix asphalt pavements is now standard practice in most jurisdictions and is referenced in ASTM D3515 [ASTM D3515, 1996]. The primary steps in the design of mixes include the determination of material properties of RAP and new materials, the selection of an appropriate blend of RAP and virgin aggregate.

To determine the amount and type of bitumen in the RAP the centrifuge test was conducted in the lab and extracted the bitumen from the pavement materials. In order to determine the bitumen percentage of the RAP using this method, three samples weighing 300 grams each were used from the three RAP's collected. First the amount of 300 grams of material was put into the centrifuge bowl, then the material was mixed with a suitable solvent. For this purpose, kerosene was used as the solvent. Then the bowl was put into the device, a filter was placed on it and the device was turned on. The speed of the device was gradually increased and the device was not stopped until the petroleum product started exiting the device. Then the device was stopped, the bowl was taken out, the materials that had stuck to the filter were separated using a spatula, the materials were placed back into the bowl again and around 270ml of kerosene was added and the device was started again.

This was repeated six times until the output solution of the device was completely clean. At the end of the test the weight of the container and the sample were measured to determine the percentage of bitumen. Using this percentage, we know how much extra bitumen to add to our samples in order to achieve the correct mix design.

The Marshall mix design procedures have been used for determining the acceptable content of recycled paving mixes and the Marshall method has been used to build our lab samples, also the same mix design as the one of the Arak-Qom project have been used in order for the quality comparison to have meaning.

The asphalt concrete samples were made using the Marshall method. A lot of efforts were made to make these samples in a controlled situation, standardized and as much as possible close to actual project conditions. The average percentage of bitumen in the RAP's from the three routes are shown in Table 1.

Making of the samples consists of three phases as below:

- Heating the aggregates and bitumen separately
- Mixing the materials
- Compaction of the mix

The samples were made using 80% RAP and 20% raw and new aggregate, in order to be the same as the Arak-Qom recycling project mix design. Three samples were made from each of the three RAP's collected. One of the nine samples was chosen as the optimum sample. In Table 2, the values of material mixtures are provided according to the weight of aggregate and percentage of bitumen.

First, the aggregate was heated at a temperature of 175-190˚c for about four hours in an oven. It is essential to heat the RAP separately. The RAP was heated for two hours at a temperature of 150 ˚c. 60/70 bitumen which was heated at a temperature of 120-130˚c was added to the mix. The bitumen being used must not be heated at this temperature for more than an hour, otherwise the physical aspects of the bitumen would change. The use of bitumen that has been heated before is also forbidden. At the next stage, after the mixture of the aggregate and the bitumen, the mixture was placed into standard cylindrical Marshall sample's with a diameter of 10cm and height of 6.25cm. The compaction of the mix was done using the Marshall hammer with the weight of 4.5 kg and 45cm height of fall. The number of hammer blows is different depending on the desired route traffic scheme. In this study the number of blows has been considered according to an average traffic model, which is 50 blows on both sides of the sample.

After constructing the asphalt samples using the above method, one sample that was technically and qualitatively better and closer to the mix design than other samples, was chosen as the optimal recycled asphalt sample.

Table 1.Average RAP bitumen percentage

No.	Location of extraction	Average bitumen percentage
1	Khorramabad-Boroujerd route	4.10
2	Khorramabad-Sepiddasht route	4.78
3	Aleshtar-Firuzabad route	4.83

Table. 2 Values of material mixtures

Location of extraction	Design bitumen %	New bitumen %	RAP %	New aggregate%	Overall bitumen & aggregate%
Khorramabad-Boroujerd route	5.00	0.90	80.00	20.00	105.00
Khorramabad-Sepiddasht route	5.00	0.22	80.00	20.00	105.00
Aleshtar-Firuzabad route	5.00	0.17	80.00	20.00	105.00

In order to choose the optimal sample after the construction of the asphalt samples, quality control tests were conducted on each of the samples. The tests and quality control standards conducted were as below:

1) Stability or strength
2) Air voids percentage

Strength is measured in terms of the ‘Marshall’s Stability’ of the mix which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60°C.

Air voids is the percent of air voids by volume in the specimen and is obtained in accordance with ASTM standard test method D3203-94.

4. Results

4.1 Air Voids Percentage

According to the mix design, the minimum air voids in the Marshall samples was 3% and the maximum was 5.2%, which the same results were obtained in both projects. The air void percentage for our optimum lab sample was 4%.

Figure 1 shows the comparison of air void percentage between Arak-Qom’s recycling project, Khorramabad-Boroujerds conventional method project and the optimum sample built in the lab

According to Figure 1:

- 80% of Khorramabad –Boroujerds conventional method samples exceeded the percentage limits which is unacceptable.
- Only 20% of Arak-Qom’s recycling method samples exceeded the percentage limits
- In general, the recycled asphalt had more similarities to the optimal lab sample than the conventional asphalt.
- According to the results, it is clear that the recycling method samples

have a more optimum air void percent compared to the conventional method.

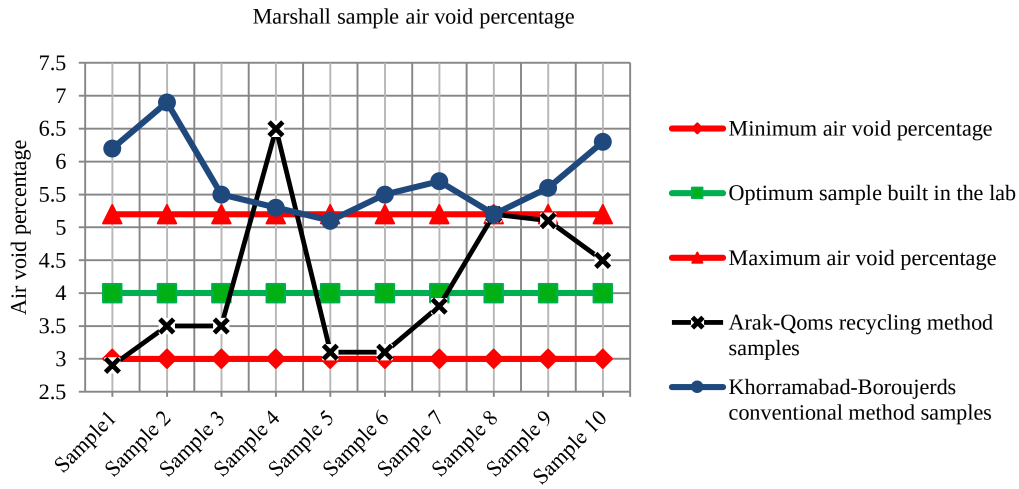

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Figure. 1 comparison of air void percentage between Arak-Qom's recycling project, Khorramabad-Boroujerds conventional method project and the optimum sample built in the lab

4.1.1 Stability

The minimum strength for the binder and topka layers for both projects, according to the mix design, was 800kg. The optimum stability for our lab sample was 1896kg. One of the most important factors in this high amount of strength, is the low air void percentage discussed above.

Figure 2 shows the comparison of stability between the recycling method (Arak-Qom's project), conventional method (Khorramabad-Boroujerds project) and optimum lab sampleAccording to Figure 2:

- Arak-Qom's project samples have a higher stability compared to Khorramabad-Boroujerds project samples
- Approximately 30% of Arak-Qom's project samples stability were identical to the optimal lab sample.
- The minimum stability required according to the mix design has been achieved by both methods.

5. Conclusions

The goal of the present study was to analyze and evaluate the data obtained from the HIR method and compare them with the data collected from the optimal lab samples, in order to review the stability of both asphalts and the factors effecting it.

According to the results of the air voids percentage in the samples, it was found that the conventional method has a high percentage of air voids in a way that only one of the ten samples were in the permitted limit range. This feature can be pointed out as the most important and obvious reason of the higher stability and strength of recycled asphalt. Therefore, the recycling method has the advantage over the conventional method.

According to the results of the stability of the samples, it was found that both methods have met the minimum limit of strength, but the recycling method has much higher strength compared to the conventional method. Therefore, the recycling method has the advantage over the conventional method in this field as well.

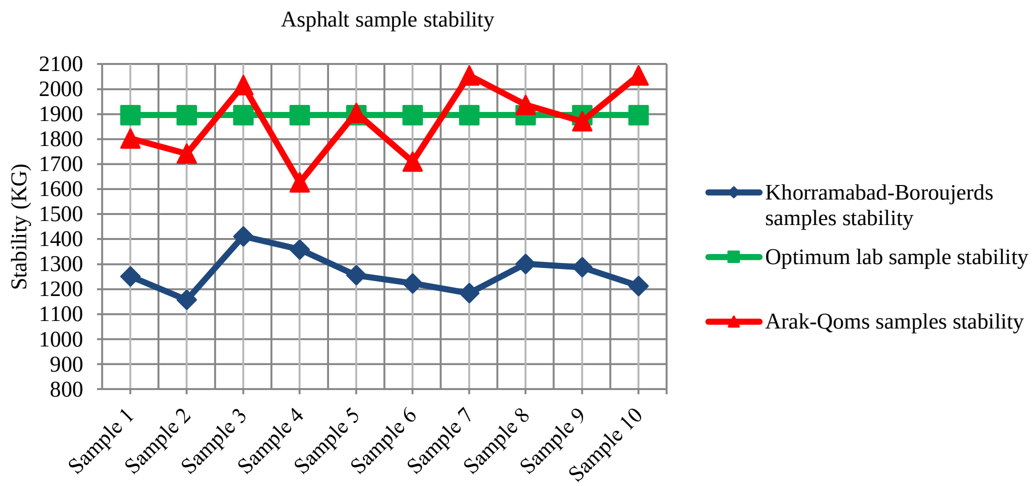

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Figure 2. Comparison of stability between Arak-Qom's recycling project, Khorramabad-Borougerds conventional method project and the optimum sample built in the lab

It was also stated in Oner and Sengoz's [Oner and Sengoz, 2015] article that the Marshall stability values related to RAP mixtures were higher and that the air void level was within the specification limits. Although our test results showed that the air void level was far better than the specification limits.

In conclusion the results showed that although both the conventional and recycling methods meet the minimum and maximum quality limits for the projects, but the recycling method has much higher qualitative characteristics compared to the conventional method.

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