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Research Paper

IMPROVEMENT OF THE MECHANICAL CHARACTERISTICS OF RECLAIMED ASPHALT PAVEMENT IN IRAQ

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The technique of Recycling Asphalt Pavement (RAP) for road construction is widely used so that RAP has been called the most recycled material in the world. RAP is most commonly used as an aggregate substitute in asphalt mix also it is used as granular sub-base or base aggregate and embankment or fill material. Unfortunately, the mechanical properties of RAP materials do not meet the requirements of State Organization for Roads and Bridges (SORB, 2003) in Iraq for sub-base and base aggregate materials, such as gradation, California Bearing Ratio (CBR), and other strength coefficients. The objective of this study was to investigate and examine different RAP/virgin aggregate blending techniques to improve the mechanical characteristics of local RAP materials in Iraq. A detailed laboratory testing program was conducted to achieve these objectives. It was found that the blending of up to 40% RAP materials with different local virgin sub-base materials improves the RAP mechanical characteristics to meet SCRB (2003) requirements for road sub-base materials and provides economical, environmental, and sustainable road construction technique in Iraq. A computerized design and management analysis which was carried out on life cycle costs of flexible pavement with unbounded sub-base layer of blended virgin aggregate materials with RAP showed savings of up to 39% of total pavement cost depending on design in comparison with conventional flexible pavement in Iraq.

Keywords: Mechanical Properties, RAP, Blending techniques, Iraq

INTRODUCTION

Overview

Most of highways and roads in the World are constructed with Hot Mix Asphalt (HMA). As the infrastructure ages, these highways and roads must be maintained and rehabilitated. The Federal Highway Administration (FHWA, 2008) estimates that 100 million tons of hot mix asphalt is milled each year in the United States only, As a result of this practice, a tremendous amount of Reclaimed Asphalt Pavement (RAP) is created every year, and

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over 80% of RAP was recycled, making asphalt the most frequently recycled material (MAPA, 2007).

RAP is most commonly used as an aggregate and virgin asphalt binder substitute in recycled asphalt paving, but it is also used as a granular base or subbase, stabilized base aggregate, and embankment or fill material. It can also be used in other construction applications. RAP is a valuable, high-quality material that can replace more expensive virgin aggregates and binders. The recycling of aggregates and other highway construction materials makes sound economic, environmental, and engineering sense. RAP is a useful alternative to virgin materials because it reduces the use of virgin aggregate required in the construction of roads.

The introduction of new asphalt milling machines in Iraq within the last few years had produced increasing amounts of RAP materials. These amounts of RAP were accumulated due to milling of old asphalt pavements of roads without any useful usage as shown in Figure 1 and 2. Agencies all around the world adopted the technique of recycling long time ago, while few research studies have been performed to characterize and examine the strength, durability, and suitability of RAP materials in Iraq.

Figure 1: Reclaimed Asphalt Materials (RAP) Used in the Study

Figure 2: Milling of Asphalt Pavement of Roads in Baghdad

Reclaimed aggregate coated with bituminous materials are processed using a technique slightly different than that used for new aggregates, but the finished product is usually requested to meet all standard material specification requirements. Unfortunately, the mechanical properties of RAP materials do not meet the requirements of State Organization of Roads and Bridges in Iraq (SCRB, 2003) for subbase and base materials, such as gradation, compaction, California Bearing Ratio (CBR), and other strength coefficients (Jadran, 2011). Therefore, it is important to improve these mechanical properties in order to be able to use them.

Taha *et al.* (1999) conducted laboratory evaluations of RAP and RAP/virgin aggregate blends used as both road base and subbase in the Sultanate of Oman. Gradation, compaction, and bearing strength tests were performed on RAP/aggregate blends of 0%, 20%, 40%, 60%, 80% and 100% RAP. The virgin aggregate was a mix of well graded sand and gravelly sand with little or no fines. RAP was obtained through milling and contained 5.5% asphalt content. The 100%

RAP produced the lowest bearing strength, with a CBR of 11. Taha *et al.* (1999) recommended that blends with 60% or less RAP were suitable for road subbase construction. For base construction, however, only mixes containing 10% RAP or less were recommended. Cooley (2005) tested sub-rounded and angular aggregate base materials, as well as RAP from two different locations. RAP contents of 0, 25, 50, 75, and 100% were utilized in a full-factorial experimental design with three replicates of each unique combination. He found that the main effect of RAP content indicate that CBR values decrease with increasing RAP contents. The addition of 25% RAP causes a 29% decrease in strength compared to the neat base material, and the strength declines 13 to 15% with each additional 25% increase in RAP content. McGarrah (2007) conducted an evaluation of current RAP practices for the Washington State DOT (WSDOT). McGarrah found that 9 states currently allowed RAP as an unbound aggregate base or subbase. A summary of McGarrah's findings on states that allow RAP as a base course material indicates that the majority of states that allow RAP in base courses limit the RAP content to a maximum of approximately 50% by weight. Mokwa and Peebles (2005) evaluated the changes in engineering properties of granular soils from various sources in Montana after blending them with RAP. The research focused on primary engineering properties including compaction, gradation, strength, stiffness, permeability, and resistance to degradation. Milled RAP was mechanically mixed at percentages of 20%, 50% and 75% by weight with four aggregates—three of them mechanically processed materials meeting the crushed base course specifications, and the fourth being a natural gravel material.

Study Objectives

The objective of this study was to investigate and examine different RAP/virgin aggregate blending techniques to improve the mechanical characteristics of local RAP materials in Iraq without the use of chemicals or stabilization additives. In addition to improve the RAP materials mechanical performance, the investigations will be extended to find the optimum percentage of RAP that can be used as a substitute to virgin aggregate from the environmental, economical, and strength point of view. RAP/ local virgin aggregate blends technique will be implemented to improve the mechanical characteristics of local RAP materials in Iraq. It was intended to conduct a laboratory testing program to achieve these objectives.

LABORATORY TESTING

Overview

A laboratory testing program was conducted on RAP using different blending techniques to study and to improve their mechanical properties. The testing program is devoted to test the reclaimed asphalt materials characteristics in the first place and then testing of mixes that contain different proportions of RAP in addition to local available virgin aggregate materials that are used in road construction. The purpose of this research was to investigate the effect of RAP content on the mechanical properties of base and subbase materials. Different RAP contents and three different local virgin base and subbase

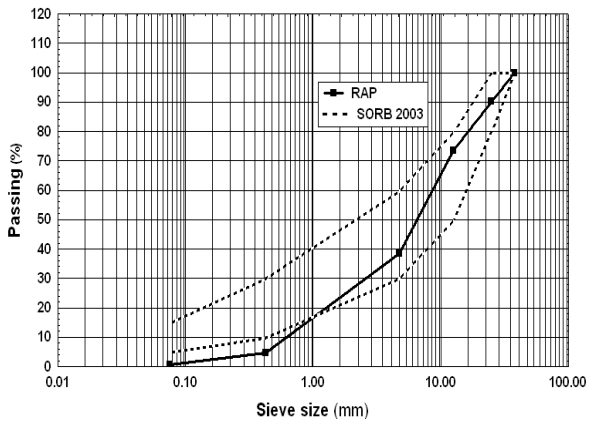
materials were studied. Three replicate samples of each possible combination were tested.

Testing of Materials

Testing of Reclaimed Asphalt Pavement Materials (RAP)

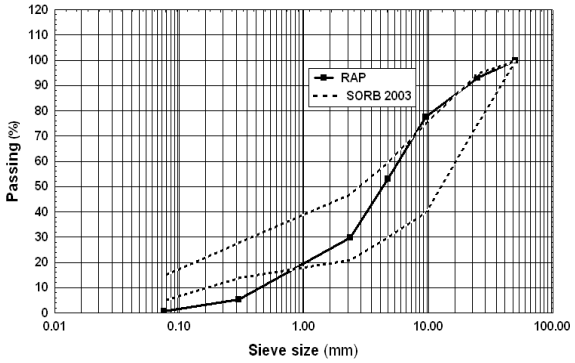
Gradation of RAP Materials: The sieve analysis test was carried out according to AASHTO standard method T27-74. Gradation test of RAP samples was carried out in order to determine the suitability of reclaimed asphalt materials for use as base or subbase materials in road construction following the specification of the state organization of road and bridges in Iraq (SCRB, 2003). Different samples were sieved and the results showed that the tested RAP samples do not meet the gradation requirements of the State Corporation of Roads and Bridges in Iraq for base as shown in Figure 3. The sieve analysis results also showed that the tested RAP materials do not meet the gradation requirements of the State Corporation of Roads and Bridges in Iraq for subbase materials as shown in Figure 4. The sieve analysis results showed that RAP materials are not suitable for use as base or subbase materials (SCRB, 2003).

Figure 3: Comparison Between Gradation of RAP and Gradation of Granular Base Materials Required by SCRB 2003-r7



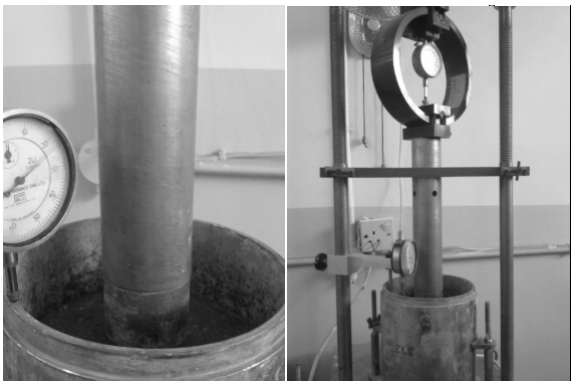
This test was carried out following ASTM D-1883, as shown in Figure 5.

Figure 4: Comparison of RAP Materials Gradation with SCRB Requirementes for Subbase Materials (SCRB 2003-R6-B)



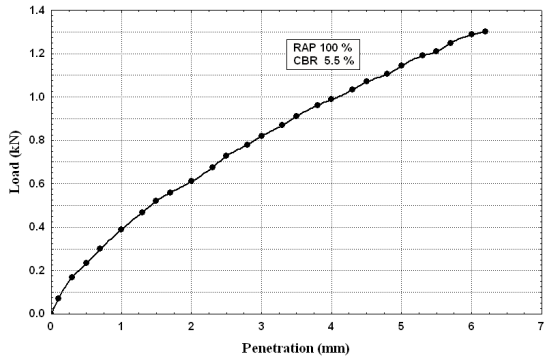
The relationship between penetration and load of CBR test is shown in Figure 6. The CBR value for the reclaimed asphalt materials was 5.5% which is not accepted by SCRB 2003 for granular base or subbase materials.

Figure 5: RAP Materials Under CBR Test Loading Machine



Effects of Blending Local Materials

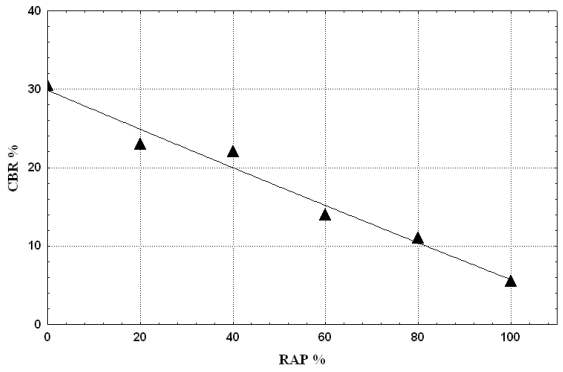
Figure 6: Relationship Between Load and Penetration of CBR Test for RAP as Subbase Materials



with RAP

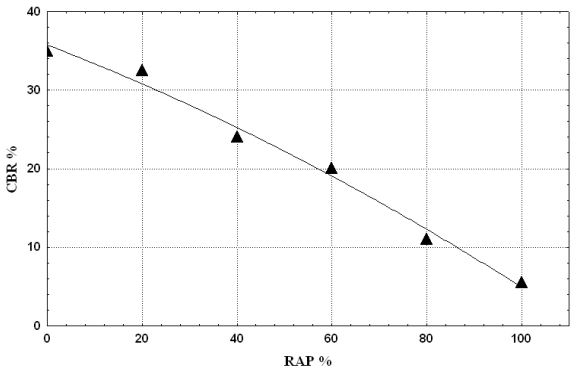
Effects of blending local virgin subbase materials with RAP: Local virgin subbase materials which were tested had low maximum dry density of 1460 kg/m^3 at optimum moisture content of 5.5%, the addition of RAP materials (which had a maximum dry density of 2000 kg/m^3 at optimum moisture content of 6.8%) increased the maximum dry density of local virgin subbase materials and reduced the optimum moisture content in general. Increasing the RAP percentage in the blend of RAP with subbase materials in general decreases the CBR value of the local virgin subbase materials as shown in Figure 7. SCRB (2003) stated that the minimum CBR of subbase materials should be more than 20% for class D. A value of CBR more than 20% can be obtained for blends of RAP and local virgin subbase materials that contains RAP materials not more than 40%. Therefore, an optimum maximum percentage of RAP of 40% can be blended with local virgin subbase materials.

Figure 7: Relationship Between CBR and Percentage of Reclaimed Asphalt Pavement Materials (RAP) in the Blend of RAP and Subbase Materials



Effects of blending local natural gravel materials with RAP: Local natural gravel materials which were tested had a maximum dry density of 2235 kg/m^3 at optimum moisture content of 6.5%, the addition of RAP materials (which had a maximum dry density of 2000 kg/m^3 at optimum moisture content of 6.8%) decreased the maximum dry density of local natural gravel materials and reduced the optimum moisture content. Increasing the RAP percentage in the blend of RAP with natural

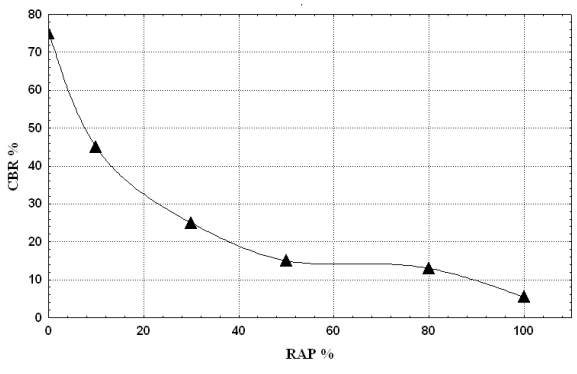
Figure 8: Relationship Between CBR and Percentage of Reclaimed Asphalt Pavement Materials (RAP) in the Blend of RAP and Natural Gravel Materials



gravel materials in general decreases the CBR value of the original local natural gravel materials as shown in Figure 8. SCRB (2003) stated that the minimum CBR of subbase materials should be more than 20% for class D. A value of CBR more than 20% can be obtained for blends of RAP and local natural gravel materials that contain RAP materials not more than 60%. Therefore, an optimum maximum percentage of RAP of 60% can be blended with local natural gravel materials.

Effects of blending local crushed aggregate with RAP: Local crushed aggregate materials which were tested had a maximum dry density of 2210 kg/m^3 at optimum moisture content of 4.8%, the addition of RAP materials (which had a maximum dry density of 2000 kg/m^3 at optimum moisture content of 6.8%) decreased the maximum dry density of local crushed aggregate materials and reduced the optimum moisture content. Increasing the RAP percentage in the blend of RAP with crushed aggregate materials in general decreases the CBR value of the original local crushed aggregate materials as shown in Figure 9. SCRB (2003) stated that the minimum CBR of subbase materials should be more than 20% for class D. A value of CBR more than 20% can be obtained for blends of RAP and local crushed aggregate materials that contain RAP materials not more than 40%. Therefore, an optimum maximum percentage of RAP of 40% can be blended with local crushed aggregate materials.

Figure 9: Relationship Between CBR and Percentage of Reclaimed Asphalt Pavement Materials (RAP) in the Blend of RAP and Crushed Gravel Materials



COMPUTER ANALYSIS OF LIFE CYCLE COST

A pavement design and management system analysis was carried out using SAMP5 computer program to determine the effects of using blends of RAP and virgin subbase materials (as unbound aggregate subbase layer) on the construction plus maintenance costs. More details about the algorithm and the operation as well as modifications of the

Figure 10: Comparison Between Pavement Layers Thickness and Type of Subbase Layer Materials Blended With Reclaimed Asphalt Pavement Materials (RAP) For 6.4 Millions 18-kip AASHTO Standard Axle Road Repetitions in 20 Years Life

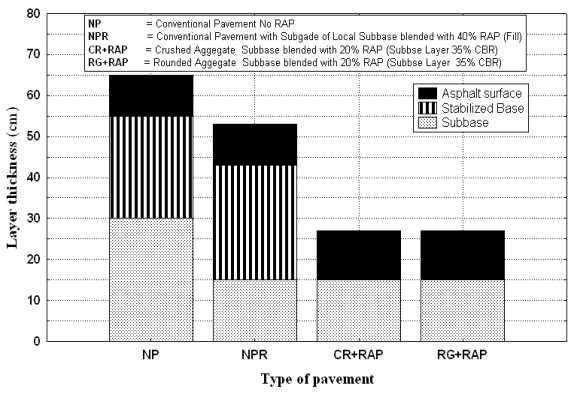
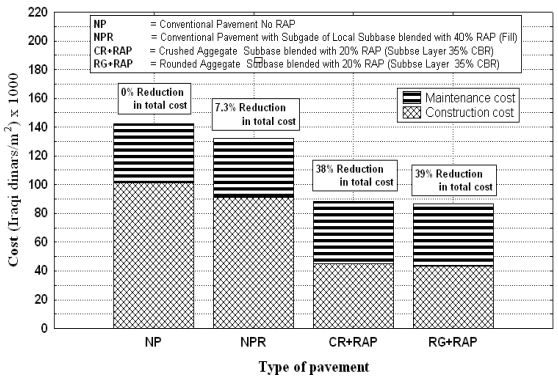


Figure 11: Comparison Between Pavement Construction, Maintenance Cost and Type of Subbase Layer Materials Blended With Reclaimed Asphalt Pavement Materials (RAP) for 6.4 Millions 18-kip AASHTO Standard Axle Road Repetitions



computer program SAMP5 are available in the literature (Sultan and Tong, 2000, and Sultan, 1995) .The computerized design and management analysis, which was carried out on life cycle costs of flexible pavement with unbounded granular subbase layer of blended virgin aggregate materials with RAP showed savings of up to 39% of total pavement cost depending on design in comparison with conventional flexible pavement in Iraq as shown in Figures 10 and 11, respectively.

CONCLUSIONS AND RECOMMENDATIONS

Effects of Blending Local Virgin Subbase Materials with RAP Materials

There are important economical and environmental benefits of reducing the quantity of local virgin subbase materials used in road construction by up to 40% due to the addition of useless RAP materials.

Effects of Blending Local Natural Gravel with RAP Materials

There are important economical and environmental benefits of reducing the quantity of local natural gravel materials used in road construction by up to 60% due to the addition of useless RAP materials.

Effects of Blending Local Crushed Aggregate with RAP

There are important economical and environmental benefits of reducing the quantity of local crushed aggregate materials used in road construction by up to 40% due to the addition of useless RAP materials.

Life Cycle Cost Analysis

The computerized design and management analysis, which was carried out on life cycle costs of flexible pavement with unbounded granular subbase layer of blended virgin aggregate materials with RAP showed savings of up to 39% of total pavement cost depending on design in comparison with conventional flexible pavement in Iraq.

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