Investigation of the Durability of RCCP Concrete Containing Various Volumetric Ratios of Asphalt Waste Against Harsh Environmental Conditions

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ABSTRACT

Over the years, asphalt road construction has been common in Iran, and today, we face a large volume of asphalt waste and debris from the damage and deterioration of these roads. These wastes are mainly transported to the outskirts and surrounding areas of cities, and there is no specific system for recycling them in industries. Additionally, the reconstruction of roads and new routes that are not subjected to heavy traffic does not require the use of first-grade, high-quality materials, as the current practice leads to an increase in the cost of construction and destruction of mines and natural resources. However, it is possible to construct many roads and routes that are not exposed to aggressive or corrosive environmental factors using recycled materials. In this study, different volumetric ratios of recycled asphalt aggregates were used to produce concrete. In this way, recycled asphalt coarse aggregates were used in different volumetric ratios of 10%, 20%, 30%, 40%, and 50% in place of natural aggregates in concrete. Other specifications and requirements were based on the national standard 14830. Furthermore, to increase the density and quality of the concrete, 10% by weight of microsilica was used. The tests conducted in this study included aggregate Los Angeles abrasion, slump, specific weight, compaction factor, water absorption (30 minutes and 72 hours), durability against freeze-thaw cycles, and assessment of concrete durability under acidic conditions. The summary of the results of this study showed that the reduction in the durability of the AS-10% design is mainly less than 10%, and it can be used in the construction of concrete pavement for low-traffic roads.

KEYWORDS

Asphalt Recycling, Roller-Compacted Concrete (RCC), Green Concrete, Concrete Durability, Recycled Materials

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1. Introduction

Nowadays, a large volume of asphalt waste and debris is generated from the deterioration and end of life of these roads. However, there is no defined or effective mechanism for recycling these wastes within the country's industries, and a significant portion of it is transported to the outskirts of cities, while the recycling rate compared to production remains very low and ineffective [1]. Renovation of roads and creation of new routes that are not subjected to heavy traffic loads, such as rural roads, pedestrian pathways, and bicycle lanes, do not require the use of first-grade, high-quality materials. This is because using primary materials in these cases not only increases construction costs but also leads to the destruction of mineral and natural resources. Summaries of previous studies show that adding asphalt waste to roller-compacted concrete causes a reduction in compressive and tensile strength and an increase in porosity. However, the use of this method for road and pathway construction in Iran's climatic conditions—which mostly include mountainous and cold regions with snowfall and freeze-thaw cycles—requires further investigation. In this regard, the use of asphalt waste in roller-compacted concrete, while reducing costs and waste, can be an effective approach, but before wide implementation, it requires careful testing and evaluation, and the role of microsilica in improving the durability of this concrete must also be examined.

2. Materials and supplies

The aggregate used has a crushed gradation with a maximum size of 19 mm and was sourced from the Dokouhak quarry in Fars Province. The recycled asphalt used in this study was collected from the stockpile of debris resulting from asphalt demolition. Its gradation was performed according to ASTM-C136, and the maximum size of the asphalt aggregate was considered to be 19 mm. The cement used in this study is Type 2, produced by Fars No. The microsilica used in this research was purchased ready-made.

3. Experimental Plan and Methods

The tests conducted in this study include determining slump, compaction, specific gravity, initial and final water absorption (at 30 minutes and 72 hours), durability against acidic conditions (after 30 and 60 days), and durability under freeze-thaw cycles (150 and 300 cycles). The laboratory program included the preparation of 78 samples. Since the specific gravity of natural aggregate differs from that of recycled asphalt aggregate, the volumetric mix design method was used. In the volumetric method, coarse aggregate replacement is done by volume (measured by a container) and then weighed. The replacement ratios of recycled asphalt aggregate were set as 10%, 20%, 30%, 40%, and 50% by volume of the natural coarse aggregate in the roller-compacted concrete. Other criteria and requirements were based on National Standard 14830. The cement content was 350 kg per cubic meter, the maximum nominal size of coarse aggregate was 19 mm, and the water-to-cement ratio was considered 0.43. Since it is recommended to use more fine aggregate or filler to improve the quality of roller-compacted concrete, microsilica was used in this study. According to the referenced standard, the maximum allowed microsilica content is 10% by weight of cement.

Table 1 Mixing plan and weight values of materials for making each cubic meter of concrete

Name	Cement	Gravel	Sand	Waste asphalt	Water	Microsilica	SLUMP
	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	CM
CONTROL	350	550	1350	0	150	35	0
AS-10%	350	495	1350	39	150	35	0
AS-20%	350	440	1350	78	150	35	0
AS-30%	350	385	1350	117	150	35	0
AS-40%	350	330	1350	156	150	35	0
AS-50%	350	275	1350	195	150	35	0

4. Results and Findings

The summary of the results obtained in this study proved that the use of low volumetric amounts of asphalt aggregate (such as the AS-10% mix design) can be applied in the construction of roller-compacted concrete pavements for use on rural roads.

Because with increased use of asphalt waste in concrete, due to the higher porosity of the recycled coarse aggregate, acid or water penetrates into the capillary pores of the concrete, which not only halts the cement hydration reaction but also causes corrosion and deterioration of the cement and concrete.

5. Discussion and Conclusion

According to the ASTM-C666-B standard recommendation, the criteria for rejecting or accepting concrete durability against freeze-thaw cycles is a maximum weight loss of more than 5% or a maximum reduction in compressive strength of more than 10%, in which case the concrete is considered deteriorated and damaged. Based on the obtained results, it can be stated that using more than 10% recycled asphalt in roller-compacted concrete will lead to deterioration and damage of the concrete.

6. Results and Discussion

The SEM images show that the concrete structure at the microscopic level is relatively dense. Microsilica particles are well-dispersed between the cement particles and the recycled asphalt waste. Additionally, microsilica has played a role in filling cracks, thereby preventing further widespread deterioration of the concrete. The images clearly demonstrate the formation of cement hydration products, with calcium silicate hydrate (C-S-H) gel—the primary binding and strength-giving material—formed uniformly. Ettringite crystals are also observed as needle-like structures, indicating a complete hydration process. Therefore, the presence of recycled asphalt particles as impurities in the concrete matrix has not created barriers nor negatively affected the hydration process. The main reason for the reduction in strength and durability of this concrete is the poor adhesion between the recycled asphalt aggregate and the cement paste, as well as the lower strength of the recycled asphalt aggregate compared to natural aggregate.

7. Conclusions

The use of any amount of recycled asphalt in roller-compacted concrete results in a reduction of the compaction factor.

The results of the initial and final water absorption tests on the concrete showed that, according to Chapter 9 of the National Building Regulations, the use of the AS-30% mix design is permitted under all environmental conditions. Furthermore, according to the ABA code, the AS-40% mix falls within the moderate category and the AS-50% mix is classified as weak.

The results of the freeze-thaw cycle test indicated that using up to 10% by volume of asphalt waste in roller-compacted concrete does not prevent its use in cold regions with long winters. However, with increasing amounts of recycled asphalt aggregate in the concrete, it should be used only in temperate or tropical climates. This is because snowfall and rainfall during cold seasons cause expansion and contraction due to freezing and thawing, which leads to surface scaling, volume increase, and deterioration of the cement paste in the concrete. Moreover, the application of deicing salts leads to sulfate penetration into the concrete, causing premature damage and deterioration.

The results of the durability test against acidic conditions showed that using at least 30% by volume of asphalt waste in roller-compacted concrete causes severe and noticeable deformation of the concrete's appearance, leading to surface degradation and exposure of the aggregates.

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