2011

Comparative performance of concrete pavements with recycled concrete aggregate (RCA) and virgin aggregate subbases

Sunghwan Kim
Iowa State University, sunghwan@iastate.edu

Halil Ceylan
Iowa State University, hceylan@iastate.edu

Kasthurirangan Gopalakrishnan
Iowa State University, rangan@iastate.edu

David J. White
Iowa State University, djwhite@iastate.edu

Charles T. Jahren
Iowa State University, cjahren@iastate.edu

See next page for additional authors

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Abstract

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Keywords

aggregates, comparative studies, concrete pavements, recycling, subbase course

Disciplines

Civil and Environmental Engineering | Construction Engineering and Management

Comments

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Authors

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Reference to this paper should be made as follows: Kim, S., Ceylan, H., Gopalakrishnan, K., White, D. J., Jahren, C. T., and Phan, T. H. (2011). "*Comparative Performance of Concrete Pavements with Recycled Concrete Aggregate (RCA) and Virgin Aggregate Subbases*." ASCE's 1st T&DI Congress, Chicago, IL, March 13-16, 2011

Comparative Performance of Concrete Pavements with Recycled Concrete Aggregate (RCA) and Virgin Aggregate Subbases

Sunghwan Kim[1], Halil Ceylan[2], Kasthurirangan Gopalakrishnan[3], David J. White[4], Charles T. Jahren[5], and Thang Huu Phan[6]

[1]Postdoctoral Research Associate, Department of Civil, Construction and Environmental Engineering (CCEE), Iowa State University, Ames, IA 50011-3232; sunghwan@iastate.edu
[2]Assistant Professor, Department of CCEE, Iowa State University, Ames, IA 5011-3232; hceylan@iastate.edu
[3]Research Assistant Professor, Department of CCEE, Iowa State University, Ames, IA 50011-3232; rangan@iastate.edu
[4]Associate Professor, Department of CCEE, Iowa State University, Ames, IA 5011-3232; djwhite@iastate.edu
[5]Associate Professor, Department of CCEE, Iowa State University, Ames, IA 5011-3232; cjahren@iastate.edu
[6]Research Assistant, Department of CCEE, Iowa State University, Ames, IA 5011-3232; thphan@iastate.edu

Abstract

Using recycled concrete aggregate (RCA) as base/subbase for road construction is alternative way to manage construction waste and reduces the need for virgin aggregates. This paper discusses the long-term performance of concrete pavements on RCA granular layer in comparison to concrete pavements on virgin aggregate granular layer. 18 representative RCA pavement sections across Iowa were primary selected considering state wide location and pavement age. Detailed visual distress surveys were conducted to identify the current pavement surface condition information and the primary distress on RCA granular layer pavement. The pavement information data for the surveyed RCA subbase sections and the corresponding virgin aggregate subbase sections in similar condition were extracted from the Iowa DOT's Pavement Management Information System (PMIS). The performance of the RCA and the virgin aggregate sections was investigated and compared in terms of the pavement condition index (PCI) and the International Roughness Index (IRI). The results indicate that RCA granular layer provides performance compared to the virgin aggregate granular layer in Iowa pavements and are performing adequately.

Introduction

Waste construction materials from rehabilitation and reconstruction have become global concerns. Historically, the most common method of managing this material has been through disposal in landfills. However, the use of these materials in landfills becomes more restrictive and the need to seek alternative uses of the waste material increases (FHWA, 2004).

Using recycled aggregate in pavement construction can reduce the need for virgin or natural aggregates, preserves the environment, and saves landfill space. In spring of 2002, Federal Highway Administration (FHWA) released a memorandum emphasizing the FHWA interest in using recycled material products in the national highway system (FHWA, 2002).

At present, recycled concrete aggregate (RCA) is mostly used in pavement granular layer, shoulder concrete, and porous granular fill, and, to a limited extent, as aggregates in new concrete pavement (Chini et al, 2001). Approximately 68 % of the RCA produced in the US is as a granular layer of base/subbase under pavements (Wilburn and Goonan, 1998). The role of pavement bases and sub-bases is to provide uniform support of pavement surface layers and adequate drainage during the lifetime of the pavement (Huang, 2003). To meet these requirements, the materials used in unbound pavement layers must meet specific particle size distributions with adequate stiffness, good durability (e.g. freeze-thaw performance), high permeability, and resistance to permanent deformation (e.g. particle crushing).

Several studies have been conducted to understand the RCA properties and specify for their use in unbound pavement layer (Miyagawa, 1991; Snyder, 1995; Chini et al., 1998; Chini et al, 2001; White et al., 2004). However, most of the previous research doses not address the long-term field performance of concrete pavement with RCA granular layer regarding engineering properties, which is required to develop proper guidelines and mechanistic-empirical design procedures.

The objective of this study is to evaluate the long-term performance of RCA granular layer pavements. For this purpose, 18 representative RCA pavement sections were selected considering state wide location and pavement age. Detailed visual distress surveys were conducted to identify the current pavement surface condition information and the most common distresses on concrete pavements that are supported with a RCA granular layer. The pavement information data for the 10 of surveyed RCA subbase sections and the corresponding virgin aggregate subbase sections in similar condition were extracted from the Iowa DOT's Pavement Management Information System (PMIS). The performance of the RCA and the virgin aggregate sections was compared in terms of the pavement condition index (PCI) and the International Roughness Index (IRI). The procedure and the results of the analysis are discussed in this paper highlighting the important findings regarding the long-term performance of concrete pavements that are supported by a RCA granular layer.

Pavement Performance Data Collection

A field experiment was carried out in 2007 to assess the long-term performance of concrete pavement with RCA granular layer. 18 representative RCA pavement sections listed in Table 1 were primary selected considering state wide location and pavement age in Iowa. The ages of most pavements selected are at least older than 10 years. The detailed current pavement performance data for the selected sections in this study were collected through the visual distress survey. The exiting pavement performance information was also extracted from the Iowa DOT's PMIS.

Table 1. RCA granular layer concrete pavement sections evaluated

Section No.	Location			PCC Thick (mm)	Subbase Thick (mm)	ADTT[a]	Construction Year
	County	Mile Post No.	Dir.				
RCA/1	I-35 in Story	119.95 to 120.05	S	305	152	5,074	1999
RCA/2	I-35 in Hamilton	140.75 to 140.80	N	267	203	4,657	2003
RCA/3	I-80 in Jasper	165.0 to 165.05	E	330	127	8,883	1996
RCA/4	I-80 in Jasper	165.20 to 165.25	E	330	178	8,870	1994
RCA/5	I-35 in Hamilton	131.40 to 131.45	N	267	203	4,709	1983
RCA/6	I-80 in Pottawattamie	10.55 to 10.60	W	330	279	5,421	1999
RCA/7	I-80 in Pottawattamie	10.55 to 10.65	E	305	N/A[b]	5,421	2003
RCA/8	I-80 in Cass	65.10 to 65.20	E	305	N/A	7,506	1988
RCA/9	I-80 in Cass	65.80 to 65.90	W	305	N/A	7,506	1987
RCA/10	I-80 in Polk	128.50 to 128.55 (Travel)	E	356	229	13,322	1994
RCA/11	I-80 in Cedar	269.00 to 269.10	E	330	152	10,777	1991
RCA/12	I-80 in Cedar	272.30 to 272.40	E	330	229	10,919	1992
RCA/13	I-80 in Cedar	272.55 to 272.65	E	330	229	10,919	1992
RCA/14	I-80 in Cedar	269.30 to 269.40	W	318	216	10,847	1992
RCA/15	I-80 in Cedar	269.10 to 269.20	W	330	203	10,847	1992
RCA/16	I-80 in Cedar	275.70 to 275.75	W	330	203	10,847	1992
RCA/17	I-80 in Cedar	. 275.90 to 275.95	W	330	203	10,847	1992
RCA/18	I-80 in Cedar	276.60 to 276.70	E	343	229	10,920	1991

a. ADTT: Average Daily Truck Traffic
b. N/A: Not Available

Visual distress survey

Visual distress surveys were conducted to gather current detailed pavement surface condition information including the extent and severity of the distress. Core samples were taken during the visual distress survey to confirm that the selected pavement sites were indeed concrete pavements with RCA granular layer. Typical RCA granular layer condition after coring is illustrated in Figure 1. The distress survey methodology used in this study was the one described in the Strategic Highway Research Program's (SHRP) "Distress Identification Manual for the Long-Term Pavement Performance (LTPP) Project." (Miller and Bellinger, 2003). The distress types and severity levels were identified using the Distress Identification Manual and recorded on the distress map sheets with the symbols. Visual survey distress map was prepared for individual test section.

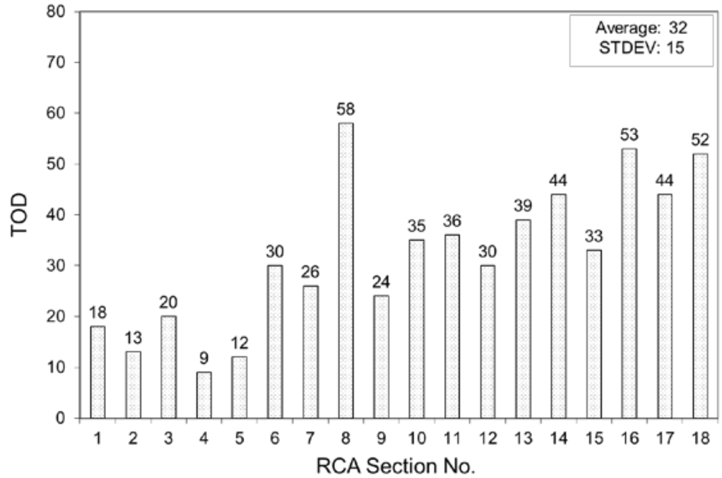
Figure 1. RCA subbase condition underneath concrete slab after coring.

Pavement performance information from PMIS

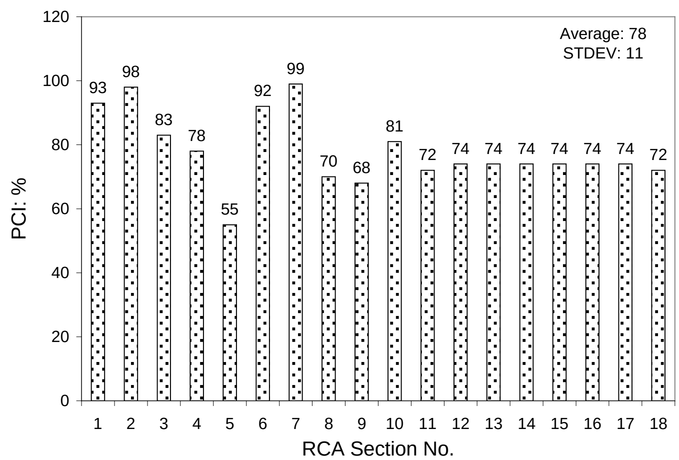
The most recent pavement performance information of 2006 for the surveyed test sections was also extracted from the Iowa DOT's PMIS. The PCI and the IRI were used as the objective measure representing the pavement performance information in this study. The PCI is a numerical index, ranging from 0 for a failed pavement to 100 for a pavement in perfect condition, to provide an index of the pavement's structural integrity and pavement surface condition. The IRI represents the severity of roughness on pavement surface computed from the measured longitudinal pavement profile.

Pavement Performance of Concrete Pavements with a RCA Granular Layer

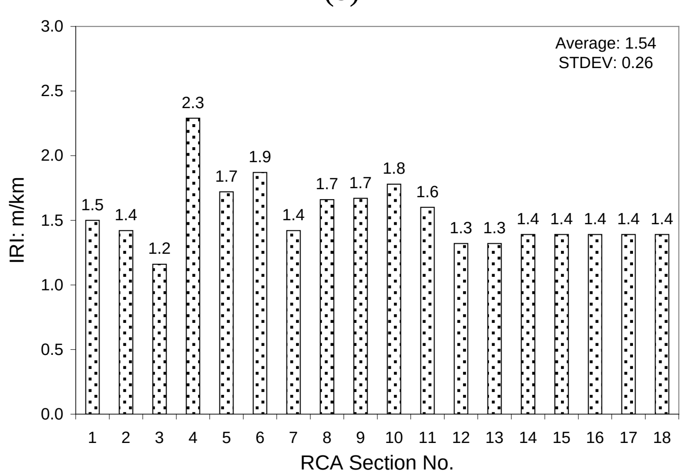
The pavement performance results for the surveyed test sections are summarized in Figure 2. The total number of distress (TOD) shown in Figure 2 (a) is the sum of number of distresses identified through the visual distress survey. Although a few popouts were observed in certain sections, these numbers were not added in the calculation of TOD since popouts do not result from subbbase problem. The values of PCI and IRI in Figure 2 (b) and (c) represent the most current measurements (2006). The average TOD, PCI and IRI value of RCA sections are 32, 78%, and 1.54 m/km, respectively. These indicate fairly good of pavement surface condition.



(a)



(b)



(c)

Figure 2. Summary of pavement performance results.

Figure 3 show the pavement surface condition on test section of RCA/15. Although a large number of pictures were taken as part of the visual distress survey for individual test sections to provide the types and severities of the distress, some representative pictures are included here which are indicative of the overall conclusion.

As seen in Figure 3, few longitudinal and transverse cracks were observed in the surveyed field test sections. The predominant distress exhibited along the all surveyed test sections are joint sealing damage and spalling. Especially, the lane-to-shoulder separation and/or the lane-to-shoulder drop off as shown in Figures 3 and 4 are often observed in the most RCA test sections. These observations are consistent with those reported by Rollings et al. (2006), who concluded that the cause of the distresses between lane and shoulder is probably due to sulfate attack on the RCA used as fill and granular layer.

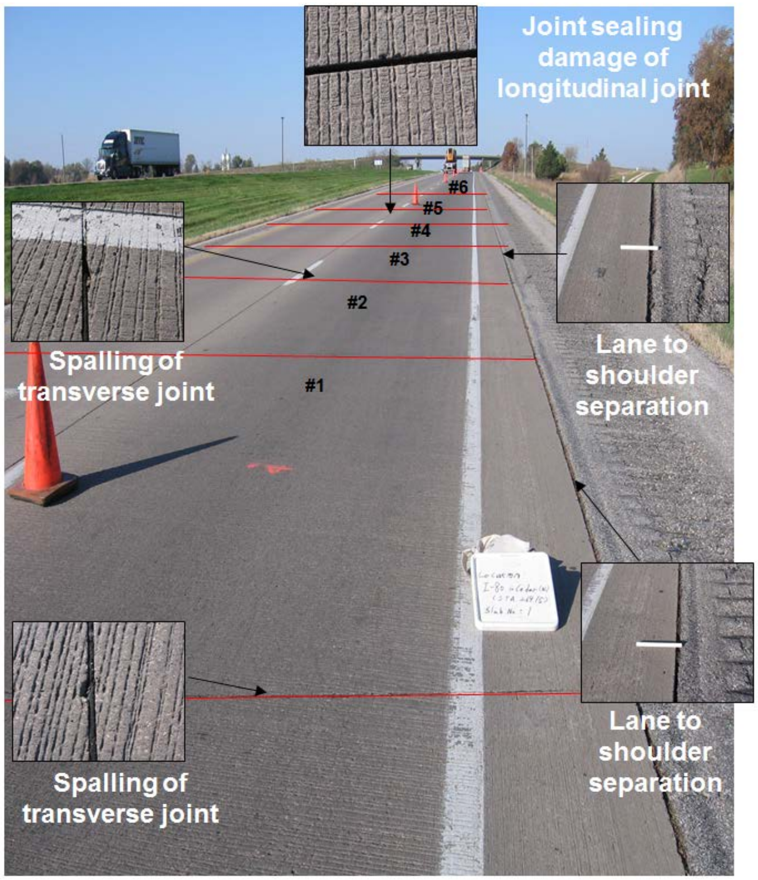


Figure 3. Pavement surface condition in test section of RCA/15 (I-80 in Cedar county mile post 269.10 to 269.20).

Figure 4. Lane to shoulder drop off in test section of RCA/5 (I-35 in Hamilton county mile post 131.40 to 131.45).

Comparison of Pavement Performances of RCA and Virgin Aggregate Sections

The virgin aggregate granular layer sections corresponded to the surveyed RCA granular layer sections in similar conditions were identified from the Iowa DOT's PMIS and listed in Table 2 for comparisons. The identified virgin aggregate section counterpart had similar traffic volume, construction year, and location but different granular aggregate layer type (virgin as opposed to recycled) corresponding to the surveyed RCA section.

Table 2. Virgin aggregate granular layer concrete pavement sections identified

Section No.	Location			PCC Thick (mm)	Sub-base Thick (mm)	ADTT*	Construction Year
	County	Mile Post No.	Dir.				
Virgin/1	I-35 in Story	117.09 to 121.48	N	292	229	5,069	1988
Virgin/2	I-35 in Hamilton	126.04 to 131.03	S	300	260	4,762	1999
Virgin/3	I-80 in Jasper	151.48 to 156.28	E	305	229	8,837	1993
Virgin/4	I-80 in Jasper	149.89 to 151.48	W	292	229	8,848	1990
Virgin/5	I-35 in Hamilton	126.04 to 130.60	N	254	203	4,763	1985
Virgin/6	I-80 in Pottawattamie	21.70 to 28.04	W	300	260	5,306	1998
Virgin/7	I-80 in Pottawattamie	20.70 to 28.04	E	300	260	5,331	1999
Virgin/8	I-80 in Cass	49.71 to 55.33	E	292	229	7,285	1989
Virgin/9	I-80 in Cass	55.33 to 59.90	W	305	229	7,478	1992
Virgin/10	I-80 in Polk	137.81 to 141.58	E	318	152	11,445	1994

*ADTT: Average Daily Truck Traffic in 2005

The vales of PCI and IRI in 2006 for the surveyed RCA subbase sections and the corresponding virgin aggregate subbase sections were extracted from the Iowa

DOT's PMIS. Figures 5 and 6 present comparison results of the RCA/1 to RCA/10 sections in Table 1 with those of virgin/1 to virgin/10 in terms of PCI and IRI.

The average PCI of RCA aggregate sections are 82 % with 14% of standard deviation while those of virgin aggregate are 74% with 13% of standard deviation. The average IRI of RCA aggregate sections are 1.65 m/km with 0.31 m/km of standard deviation while those of virgin aggregate are 1.48 m/km with 0.20 m/km of standard deviation. The paired t-tests were performed to evaluate if the PCI and IRI obtained under the RCA sections are statistically different from those under the virgin aggregate sections. A paired t-test uses the mean of difference between the observations in one group and the matched observations in the other group (SAS, 2005). In the Figures 5 and 6, the symbol 'μ_D' indicates the mean of differences between the PCI or IRI in the RCA sections and those in the corresponding virgin aggregate section; thus accepting null hypothesis, i.e., the PCI or IRI values in both of test sections are not significantly different. These results indicate that the RCA granular layer provides at least similar, if not better performance compared to the virgin aggregate layer in Iowa pavements and are performing adequately.

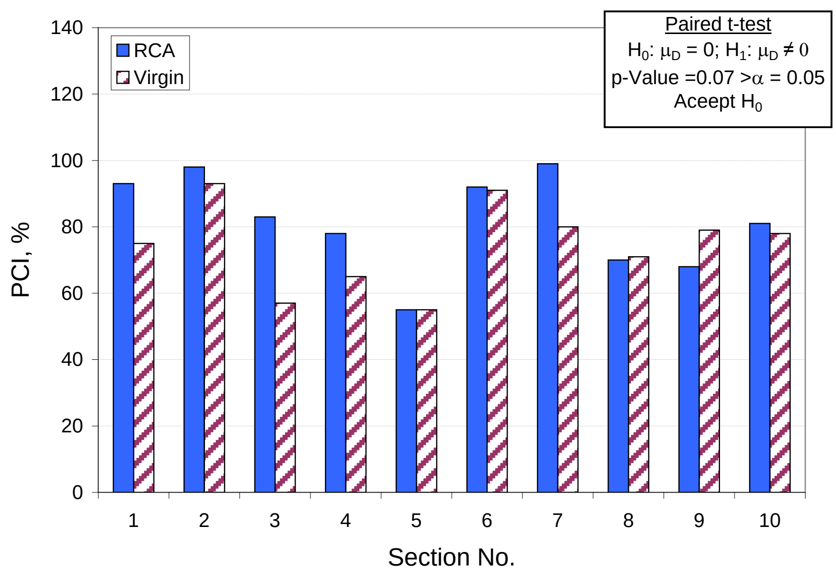


Figure 5. PCI values for the RCA and the virgin aggregate sections.

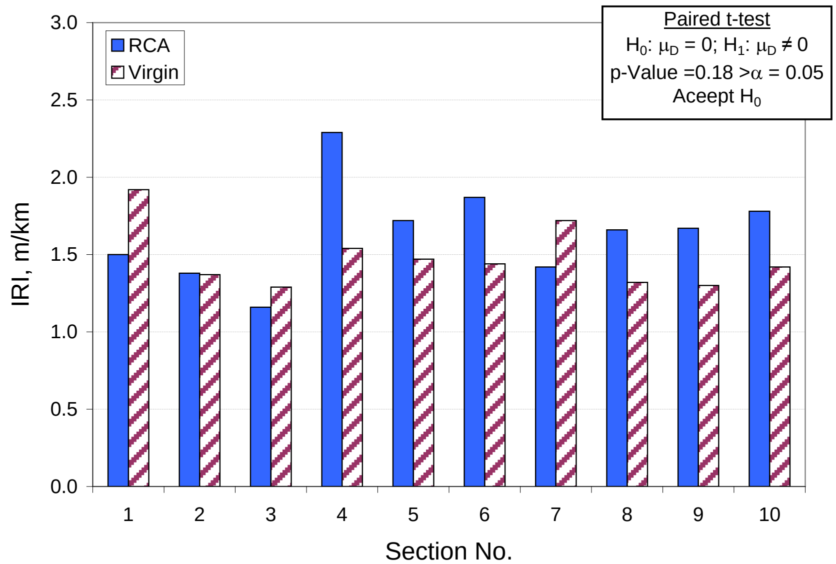


Figure 6. IRI values for the RCA and the virgin aggregate sections.

Conclusions

This study investigated the long-term field performance of concrete pavement with Recycled Concrete Aggregate (RCA) granular layer. Based on the results of this study, the following observations were drawn:

- Based on the evaluation of representative RCA pavement sections, a RCA granular layer provides performance compared to a virgin aggregate granular layer in Iowa pavements and is performing adequately.
- Few structural distresses such as longitudinal and transverse cracks were observed on all RCA pavement test sections evaluated in this study. The featured distresses on RCA are the lane-to-shoulder separation and lane-to-shoulder drop off, which are consistent with the findings reported by previous researchers.

Acknowledgements

The authors gratefully acknowledge the Iowa Department of Transportation (Iowa DOT) and the Iowa Highway Research Boards (IHRB) for supporting this study. The contents of this paper reflect the views of the authors who are responsible for the facts and accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the Iowa DOT. This paper does not constitute a standard, specification, or regulation.

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