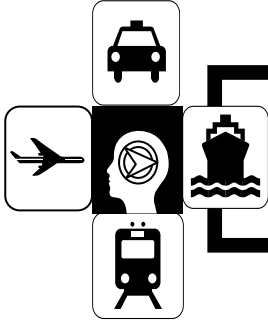


# JERSEY DOT'S

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## Tech Brief

### The Use of Recycled Concrete Aggregate in a Dense Graded Aggregate Base Course

FHWA-NJ-2008-002

April 2009

SO, HERE'S THE PROBLEM...

- Recycled Concrete Aggregate (RCA) has been used for Dense Graded Aggregate (DGA) Base Course since the mid 80's.
- However, recent research conducted by the NJDOT has indicated that although RCA exhibits superior structural properties, the permeability is very low when compared to typical base course aggregates used in New Jersey.
- Research is needed to determine how the NJDOT can continue to use this valuable recycled material without detrimental effects of the low permeability. Possible areas of research include pavement design considerations such as when is permeability not important or a low permeability material is preferable. Also, since the RCA material is structurally excellent without good permeability, how do we increase the permeability to make it better for use in a base course application? The Department of Transportation has a responsibility to be environmentally friendly and should promote recycling but we must also consider the infrastructure and prudently use recycled materials in applications where appropriate. Guidelines are needed to maximize the use of recycled materials without being detrimental to the infrastructure.
- Along with the RCA evaluation, the Department is currently evaluating the use of a non-nuclear gauge for measurement of moisture and density by time domain reflectometry (TDR) according to ASTM D 6780. The use of TDR gauges to determine moisture content and density of RCA has not been previously researched. Laboratory and field testing is needed to investigate the use of this new technology with RCA and RCA blends.

AND, HERE'S OUR SOLUTION

- Develop and distribute a survey to the different state agencies to determine if they are using recycled concrete aggregate (RCA) and have had pavement failure issues due poor permeability;
- Sample recycled concrete aggregate (RCA) from three different NJDOT approved sources and conduct permeability and California Bearing Ratio testing;

- Provide recommendations to NJDOT on how to modify the current RCA specification to allow for potentially better permeability while maintaining required pavement design strength requirements;
- Procure TDR equipment and conduct a field study using 5 different field sources and aggregates. Each field section would be compared to conventional nuclear gauge testing.

We set out to characterize RCA samples for stability and permeability, such as (Figure 1):



(a)



(b)

Figure 1 – (a) California Bearing Ratio (CBR) and (b) Constant and Falling Head Permeability Set-up for Coarse Aggregates

The different RCA sources (from the three regions) were found to be consistent with respect to both the permeability and CBR values. In all cases, the permeability was lower than expected with the CBR values high (> 100%). However, even though the permeability measurements of the RCA were low, information gathered from NJDOT concluded that to date not one single pavement failure in New Jersey had been attributed to poor permeability of aggregate base course, even when RCA had been used. However, mixed results regarding pavement failures and RCA were found from the survey conducted of the different state agencies. In total, 25 state agencies had responded to the survey (Figure 2). Overall, the survey indicated:

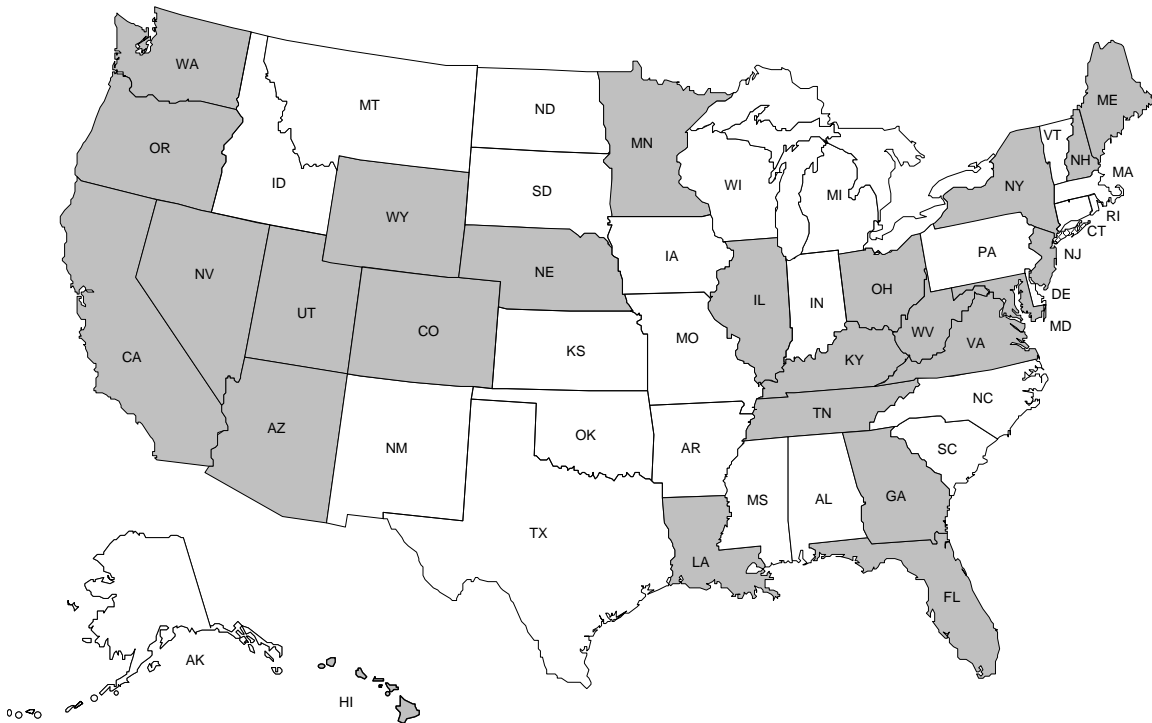


Figure 2 – State Agencies that Responded to RCA Survey

Some states had pavement drainage issues while others did not. These states are further identified below:

- State agencies using RCA with no drainage-related pavement failures
  - Florida, Minnesota, and Washington
- State agencies using RCA with drainage-related pavement failures
  - California, Georgia, Illinois, Louisiana, and Nebraska

The aggregate specifications for the base aggregate use of RCA was obtained and compared to determine how the “Good vs Poor” states compared. Table 5 shows this comparison. Immediately, one can see that states that use the 2 inch sieve as the top sieve (i.e. – all RCA screened over the two inch sieve) reported to have no drainage-related pavement failures. Meanwhile, the state agencies who reported pavement failures related to poor drainage all had top sieve sizes of 1 ½ inches, except for Georgia DOT. Georgia DOT, along with Illinois DOT who also reported drainage issues, allow eleven (11) and twelve (12) percent fines in their RCA aggregate base course, respectively. The research conducted by Bennert and Maher (2005) clearly illustrated the “clogging” that occurs when the aggregate base course material has a fines content around 10%.

Therefore, based on the preliminary findings of the survey, the following two items should be investigated to increase the permeability (drainage) of RCA:

1. Utilize the blending of different aggregate materials to help increase the drainage performance of the RCA; and

2. Increase the processing size (top size) of the RCA to 2 inches from its current 1.5 inch top size.

Previous research at Rutgers University had indicated that blending RCA with an NJDOT I-3 (bank-run rounded gravel) had helped increase the permeability but had a detrimental affect on the CBR. Further testing in this study validated those results (Table 1). NJDOT I-9 was also utilized with very successful results in increasing the permeability. Unfortunately, it had devastating effects on the CBR of the RCA material. Additional blending with a finer sand showed minimal improvement with permeability, while dropping the CBR value.

Table 1 – Permeability and CBR Values for RCA Blends

Region of NJ	Soil Gradation Type	Permeability from Constant Head Test (ft/day)	California Bearing Ratio at 0.1"
<b>RCA + NJDOT I-3</b>	100% RCA	0.3	169
	75% RCA, 25% I-3	1.9	129
	50% RCA, 50% I-3	8.5	80
	25% RCA, 75% I-3	13.0	67
<b>RCA + NJDOT I-9</b>	75% RCA, 25% I-9	27.3	87
	50% RCA, 50% I-9	66.8	43
<b>RCA + Dredge Sand (D.S.)</b>	75% RCA, 25% D.S.	0.1	107
	50% RCA, 50% D.S.	1.9	69

After the blending experiment showed little success, the next phase was increasing the top size of the RCA. The South Jersey approved sources, AE Stone, adjusted their processing of RCA to provide material to test. From a gradation standpoint, processing the RCA over the 2 inch sieve decreased the percent passing for material finer than the No. 8 sieve (i.e. – 2.36 mm and less) by approximately 3 to 4%. The percent fines decreased from 4.6% to 3.5% when the RCA was processed/screened over the 2 inch sieve as well.

Permeability and CBR testing was conducted using the two differently processed RCA materials. The laboratory results show that increasing the top size to 2 inches from 1.5 inches increased the permeability to almost 6 ft/day while also increasing the CBR value to 133% (Table 2). Although the permeability would still be classified by the AASHTO Pavement Design Guide (1993) as Poor to Fair, it is still five times greater than when the RCA is processed/screened over the 1.5 inch sieve, without sacrificing the stability of the aggregate base layer.

Table 2 – Influence of RCA Processing on Permeability and CBR Values

Soil Gradation Type	Permeability from Constant Head Test (ft/day)	California Bearing Ratio at 0.1"
1.5" Top Size RCA	1.2	122
2.0" Top Size RCA	5.9	133

For the TDR evaluation, 5 test locations were selected for comparison to the nuclear density gauge. A second device, called the Electrical Density Gauge (EDG), an experimental non-nuclear device being manufactured by Humboldt Equipment, was lent to Rutgers University to also evaluate (To date, neither the TDR nor the EDG devices had not been used successfully on coarse, aggregate materials). Photos of the TDR and EDG in the field are shown in Figures 3 and 4.



Figure 3 - Moisture Density Indicator-MDI 2000 (TDR) Setup



Figure 4 - Electrical Density Gauge (EDG) Setup

### ***HERE'S WHAT WE CAME UP WITH...***

- The overall performance of the RCA among the three different suppliers sampled for the study showed that RCA can be classified as having a low permeability and high stability/bearing strength for pavement design applications. The permeability of the three different sources ranged from 0 to 1.2 ft/day, while the CBR ranged from 112% to 169%.
- It appears that the best material to blend with RCA to increase the permeability, while not decreasing the overall stability/bearing strength is DGABC. The use of RAP, NJDOT I-3, and poorly graded sand all slightly increased the permeability of the RCA. The NJDOT I-9, sampled from the Rt 30/Delilah project was able to increase the permeability to over 60 ft/day at a 50:50 blend with RCA. Unfortunately, at this ratio, the final blend was very difficult to compact in the laboratory mold and the final CBR results were much lower than expected.
- Although based on limited testing at one Regional source (South Region – A.E. Stone), changing the processing/screening of RCA from a 1.5 inch to a 2 inch top size sieve, the permeability of the RCA increased from 1.2 ft/day to 5.9 ft/day, while also increasing the CBR value from 122% to 133%.
- An evaluation of the MDI developed by the University of Purdue and manufactured by Durham GeoSlope was conducted for the NJDOT to determine its suitability for use in the construction control of mostly dense graded aggregate

base layers. The one-step method because of its ease and expediency in the field was favored over the two-step method.

- Field evaluation involved the collection of density and moisture contents from five different project sites that consisted of either compacted dense graded aggregate base layers and or compacted porous fills. Dry densities and moisture contents measured with the MDI were compared with those from nuclear density gauges. In general, both the nuclear gauges and the MDI recorded very similar moisture contents. However, differences of up to 12.53% were observed in the dry density measurements. For the most part, the dry densities recorded by the MDI were less than those from the nuclear gauges. Better agreements were obtained for the moisture content.
- The required calibration constants were determined using a 4-in mold after sieving through the No.4 sieve (similar to AASHTO T99, Method C). Due to the large size of the DGA, a 6-in mold as per ASTM, would have been more suitable for the sample sizes. However, the 6-in mold laboratory calibration setup is not available when the study was conducted. The differences in the dry densities may be due to the calibration constants were not being representative of the insitu materials as the lab tests were conducted on the finer fractions that made up a small fraction of the gradation. Furthermore, Drnevich stated that the current method is limited to samples with more than 30% passing sieve number 4 and particle size not greater than  $\frac{3}{4}$  inch.
- Measurements from the EDG were not discussed further because of the bias introduced by using the nuclear gauge for the field calibration. The results from the EDG could therefore not be compared those from the nuclear gauge. However, recommendations were provided to the manufacturer (Humboldt Manufacturing Company) on improving the device and incorporating a laboratory calibration component.

## FOR MORE INFORMATION CONTACT

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A final report is available online at

<http://www.state.nj.us/transportation/research/research.html>

If you would like a copy of the full report, please FAX the NJDOT, Division of Research and Technology, Technology Transfer Group at (609) 530-3722 or send an e-mail to [Research.Division@dot.state.nj.us](mailto:Research.Division@dot.state.nj.us) and ask for:

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