Date: July 2013

The Use of Recycled Concrete Aggregates (RCA) for Temporary Pavements

Nebraska Department of Roads

Research Project: The Use of Recycled Concrete (RCA) for Temporary Pavements

Location: Barneston West

Starting Date: May 2013

Completion Date: July 2013

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BACKGROUND OF THE IN-HOUSE INVESTIGATION:

Nebraska Department of Roads (Material and Research) started an experimental field trial on temporary pavement using crushed concrete obtained from the removal of old PCC pavements.
The specific definition for Recycled Concrete Aggregate (RCA) is a granular material manufactured by removing, crushing, and processing hydraulic-cement concrete pavement for reuse with a hydraulic cementing medium to produce fresh paving concrete. The aggregate retained on the 4.75 mm sieve is called coarse aggregate and the material passing the 4.75 mm sieve is called fine aggregate.
The temporary pavement test section used at Barneston West, NE was scheduled to be removed after 30 days of placement. This project was the best candidate for the RCA field trial to analyze materials handling issues associated with the use of recycled materials.

DESCRIPTION OF THE INVESTIGATION (TASKS):

I. Summarize combined aggregate gradations performed.
II. Evaluate mechanical and permeability properties of the mix design using RCA.
III. Address material handling issues associated with the use of recycled materials (stockpiles)
IV. Identify site construction practices for placement using RCA.
V. Identify failures, causes, and lessons learned.
VI. Identify cost savings from the use of recycling and materials.

SUMMARY OF INVESTIGATION BY TASKS

TASK I&II- Evaluation

The cylinders were made in the field and were brought to the central laboratory in Lincoln. The fabrication and curing of all cylinders was conducted according to specifications ASTM C39. The 47B mix design was used in all combined aggregate gradations. The description of the proportioned mix designs and test results are shown in Table 1.

Table 1. Description of Proportioned Mix Designs and Test Results

Performed	*Proportioned Mix Designs	W/CM ratio	Field Air Measured	7 Days Compressive Strength (psi)	28 days Compressive Strength (psi)	Freeze & Thaw (Percentage)	Permeability	Modulus of Elasticity (Ksi)
NDOR's Req.		Max 0.48	7.5-10 %	3000 min. psi @ 28 days		Durability >70% 300 cycles	NA	NA
May 2013	30% RCA-70% 47B Fine	0.38	7.6	3120	3970	NA	High	NA
May 2013	40%RCA-60% 47B Fine	0.38	8.5	2620	3560	75%	NA	3.2
June 2013	50% RCA-50% 47B Fine	0.42	8.1	2069	2839	NA	NA	NA

The combined aggregate gradation using the different percentages of RCA was calculated as a percent passing by weight on each sieve size to compare it to the maximum and minimum tolerance limits per the 47BR Specification. The results were then plotted in a spreadsheet developed by the 0.45 power curve concept. It was created by plotting the cumulative percent passing (y-axis) versus the sieve raised to the 0.45 power (x-axis). The chart displays the maximum and minimum limits for the 47B Revised gradation band by plotting the cumulative percent passing versus the sieve sizes.

Figure 1, 2 and 3 are shows the analysis of the combined aggregate gradations performed on the temporary pavement paving applications at Barneston West. The combined gradations for Figures 1 and 2 where outside of the gradation tolerance; however, the research team considered it important to address the maximum percent replacement of RCA in order to analyze the impact of performance, material handling issues (stockpiles) and its effects during the concrete placement .

Figure 1. Combined Aggregate Gradations 30% RCA - 70% 47B Fine

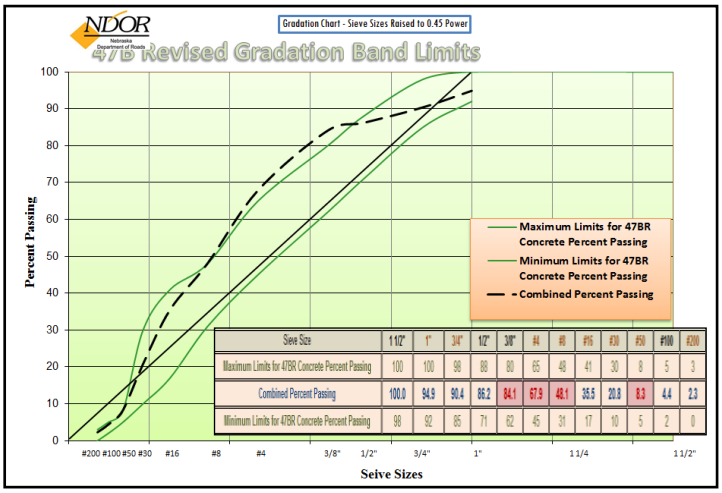


Figure 2. Combined Aggregate Gradations 40% RCA - 60% 47B Fine

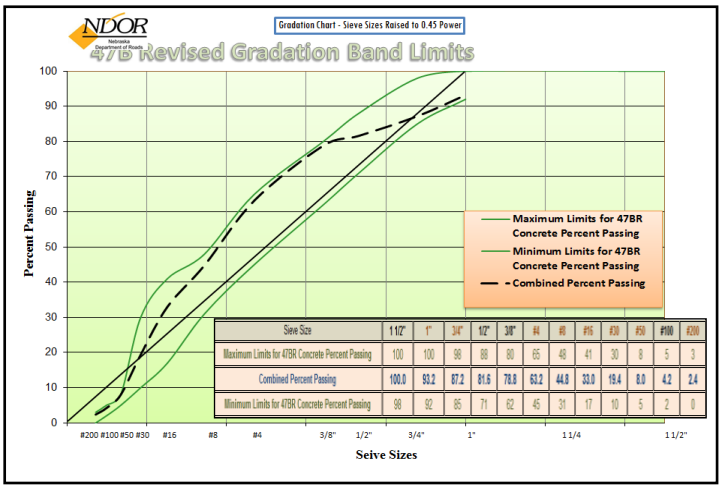
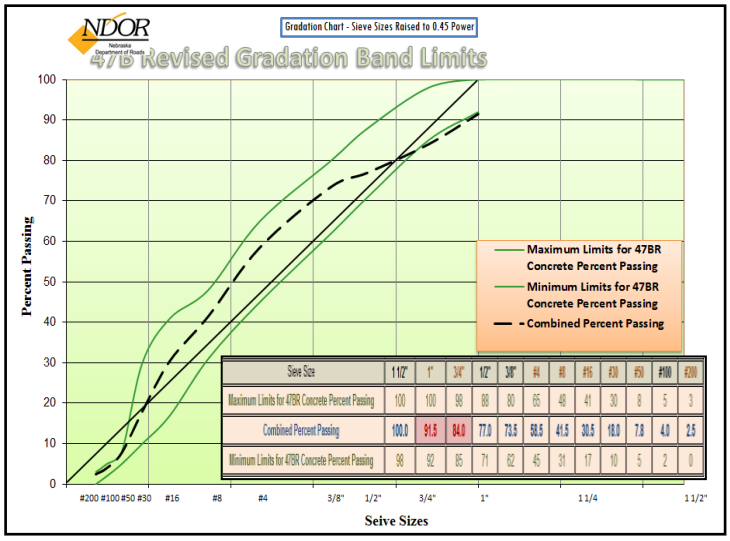


Figure 3. Combined Aggregate Gradations 50% RCA - 50% 47B Fine



TASK III & IV- Evaluation

This part of the evaluation was intended to observe the field application on the material handling issues associated with the use of recycled materials (stockpiles). Also, identify site construction practices for placement using RCA.

Field Observations:

- The use of RCA in new concrete initially created problems with mix workability. The problem was associated with the high absorbency of water and the difficulty in maintaining a consistent and uniform saturated surface dry condition of RCA aggregate. Figures 4 and 5 show the sample of RCA and the excess of fines. The Contractors overcame this hurdle by improving their process control program. Their process control program heightened their awareness of the need to water stockpiles and to conduct frequent testing of RCA aggregate for moisture content. Figures 6 and 7 show the placement of 40%RCA-60% 47B Fine.

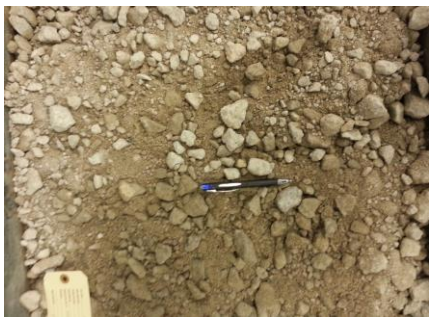


Figure 4 . Aggregate Sample for 40%RCA- 60% 47B Fine

Figure 5. 40%RCA-60% 47B Fine Sample amount of fines

Figure 6. Placement of 40%RCA-60% 47B Fine

Figure 7. Placement Characteristic of 40%RCA-60% 47B Fine

- The strength performance was found to have lower compressive strengths while using RCA in a PCC mix, due to the increase in fines. This is documented in the American Concrete Institute's report titled "Removal and Reuse of Concrete" based on information from Detroit in 1992. This is due to natural fine aggregate having a higher strength than recycled fines. The significant portion of the fines in a recycled aggregate is mortar from the original concrete mix. The majority of this strength loss is attributed to the material smaller than 2 millimeters (0.08 inches). Table 2 shows the core final strength for each section evaluated. Figure 8 is showing the core visual inspection.

Table 2. Core Strength Results

Performed	*Proportioned Mix Designs	28 days Compressive Strength (psi) Cores
NDOR's Req.		3500 min. psi @ 28 days
May 2013	30% RCA-70% 47B Fine	4260
May 2013	40%RCA-60% 47B Fine	3750
June 2013	50% RCA-50% 47B Fine	2510

Figure 8. Core Visual Observation 40%RCA-60% 47B Fine

TASK V - Identify failures, causes, and lessons learned :

The following identify failures, causes, and lessons learned:

- Because recycled aggregate contains mortar from the original concrete, it is more porous and absorptive than many natural aggregates. Recycled aggregate had water absorption of 9.6%.
- The workability of concrete, as the amount of recycled aggregate was increased, the concrete required more water to maintain adequate consistency. This was attributed to the angular shape and possibly the water absorption of the recycled aggregate.
- Field gradation at the time of placement changed due to stockpiles handling, which is a concern for its effects during the concrete placement and the long term performance. However, for this field trial the temporary pavement test section used at Barneston West, NE was scheduled to be removed after 30 days of placement.
- The strength performance was found while using RCA in a PCC mix lower compressive strengths, due to the increased in fines.

TASK VI – Identify cost savings from the use of recycling and materials Evaluation:

The following cost estimates were provided by Ray Wagner of the Beatrice Concrete Co.; Inc. as follows:

- The CRUSHED CONCRETE is on site (therefore no delivery costs)
- The price for CRUSHED CONCRETE is $5.00 a ton.
- The price of 47B stone delivered to plant site is $20.00 a ton. (This cost would vary significantly depending on distance to be hauled and the picked up price of 47B stone).

With these costs factors used, the savings for the following replacements are:
30% CRUSHED CONCRETE replacement.....$7.00 cu. yd.
40% CRUSHED CONCRETE replacement.....$9.50 cu. yd.
50% CRUSHED CONCRETE replacement.....$12.50 cu. yd.

For Beatrice Concrete case to haul the crushed concrete to Beatrice from the HWY 2 plant, therefore reducing the plant savings. But most likely the crushed concrete would be on site.

Summary:

The use of RCA as an option for coarse aggregate has great possibilities for temporary pavement only. RCA in concrete creates workability inconsistencies, which is associated with the high absorbency of water and the difficulty in maintaining a consistent and uniform saturated surface dry condition of RCA aggregate. The handling of stockpiles, the breaking down of crushed concrete creates an inconsistency of gradations, especially on the fine side of the gradation. There is a minimum risk to the Department with a maximum replacement of 30% of RCA in temporary pavement and used only on temporary pavement that will be removed the same construction season.