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 were 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.

- 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>
<thead>
<tr>
<th>Performed</th>
<th>*Propportioned Mix Designs</th>
<th>28 days Compressive Strength (psi) Cores</th>
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<tr>
<td>NDOR’s Req.</td>
<td>3500 min. psi @ 28 days</td>
<td></td>
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<tr>
<td>May 2013</td>
<td>30% RCA-70% 47B Fine</td>
<td>4260</td>
</tr>
<tr>
<td>May 2013</td>
<td>40% RCA-60% 47B Fine</td>
<td>3750</td>
</tr>
<tr>
<td>June 2013</td>
<td>50% RCA-50% 47B Fine</td>
<td>2510</td>
</tr>
</tbody>
</table>
**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.