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Use of Recycled Crushed Concrete (RCC) Fines for Potential Soil Stabilization

Nebraska Department of Roads

Research Project: Use of Recycled Crushed Concrete (RCC) Fines for Potential Soil Stabilization

Location: Material & Research

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Hwy 75 Waste RCC

Hwy 75 Waste RCC

OBJECTIVE OF THE INVESTIGATION:

This study evaluated the use of Recycled Crushed Concrete (RCC) Fines for potential soil stabilization. Soil stabilization is the enhancement of subgrade stability to improve the constructability of successive pavement layers. Use of RCC fines may not only provide less costly alternatives for subgrade stabilization, but their use may also alleviate landfill disposal challenges.

DESCRIPTION OF INVESTIGATION:

1. Evaluate the performance/effectiveness of laboratory mix design procedures in predicting field performance.
2. Evaluate Soil Liquid Limit (LL) per AASHTO T 89, Plastic Limit (PL) and Plasticity Index (PI) in accordance with AASHTO T 90, of virgin and lime stabilized soils.
3. Evaluate the unconfined compressive strength (q_u) in accordance with AASHTO T 208 of virgin and lime stabilized soils.

LABORATORY INVESTIGATION

Tasks proposed for this investigation:

- Mechanical Evaluation
    - Components of Stabilization by Task

Task 1:
Soil Gradation

- Virgin Soils
- Soils with RCC
- Soils with lime and RCC

Task 2:
PH Level

- Soils of high, medium and low plasticity with Lime in accordance with ASTM C 977 “Standard Specification for Quicklime and Hydrated Lime for Soil Specification”.
- Soils of high, medium and low plasticity with Lime and RCC material in accordance with ASTM C 977 “Standard Specification for Quicklime and Hydrated Lime for Soil Specification”.

Task 3:
Mechanical Properties
Evaluation of mechanical properties of High, Medium and Low Plasticity Soils with Lime and RCC

- Decreased cohesiveness (Plasticity)
- Decreased volume expansion or compressibility
- Increased strength

LABORATORY TESTING:

As described in the laboratory investigations under Task 1, the investigation proceeded first with the gradation evaluation of virgin soils of High, Medium and Low PI. Table 1 provides the sieve analysis of the Waste RCC and virgin soils used in the investigation.

Table 1.

Sieve Analysis Total Percent Passing									
Soil Index	Sample ID-	No.3/8	No.4	No.10	No.30	No.40	No.50	N.100	No.200
NA	Waste RCC - Hwy 31	100	98	89	56	45	36	20	9
	Waste RCC -Hwy 75	99	88	56	32	28	25	17	13
Low	Virgin Soil-Low PI	-	-	100	99	98	97	94	92
Medium	Virgin Soil-Medium PI	-	-	-	100	99	99	99	98
High	Virgin Soil- High PI	-	-	100	100	100	99	98	97

Table 2. shows the sieve analysis performed on soils with Waste RCC added and with Waste RCC and lime added. Sieve analysis results show that the addition of the 3% Waste RCC does not change the gradation of the virgin materials significantly. However, with the addition of lime the percent passing the #30 through #200 sieve sizes shows a change. Different percentages of lime were used depending on results of pH level evaluation shown in Table 3. The percent lime added to the medium and high PI soil was 4% and for the low soil index was 2%. It is clear that the lime changed the gradation, causing the material to become coarser.

Table 2.

Sieve Analysis Materials Combinations- Total Percent Passing									
Soil Index	Sample ID-	No.3/8	No.4	No.10	No.30	No.40	No.50	N.100	No.200
Low	Soil w/ 3% RCC- Hwy 31	-	-	100	99	97	95	91	89
	Soil w/ 3% RCC- Hwy 75	-	-	100	98	97	95	91	89
	Soil w/ 3% RCC - Hwy 31 and 2% lime	-	-	100	97	95	90	81	75
	Soil w/ 3% RCC - Hwy 75 and 2% lime	-	-	100	97	93	88	79	73
Medium	Soil w/ 3% RCC- Hwy 31	-	-	100	99	99	98	97	97
	Soil w/ 3% RCC- Hwy 75	-	-	100	98	98	98	97	97
	Soil w/ 3% RCC - Hwy 31 and 4% lime	-	-	100	81	76	69	62	58
	Soil w/ 3% RCC – Hwy 75 and 4% lime	-	-	100	79	72	67	60	57
High	Soil w/ 3% RCC- Hwy 31	-	-	100	99	99	98	97	95
	Soil w/ 3% RCC- Hwy 75	-	-	100	98	98	97	96	95
	Soil w/ 3% RCC - Hwy 31 and 4% lime	-	-	100	68	60	52	41	33
	Soil w/ 3% RCC - Hwy 75 and 4% lime	-	-	100	83	75	66	51	43

Part of the study consisted of evaluating the virgin soil chemical PH level for each soil type, with the addition of the 3% waste RCC material, and with lime and with waste RCC material. The soil pH was tested in accordance with ASTM C 977. Different percentages of lime were added to the soil in order to reach a pH soil level of 12.40 to stabilize the soil. The testing for pH levels is used to determine the percent lime that is required for the soil type; in order, to increase the unconfined compressive strength and decrease plastic index. The following Table 3 shows the results of the materials tested.

Figure 1. PH Level Soil Samples

Figure 2. PH Level Testing

Table 3.

Lime (%) Added	LOW PI Soil		
	LOW PI Virgin Soil	Soil with 3% RCC - Hwy 31	Soil with 3% RCC - Hwy75
	PH (ASTM C 977)		
0	7.48	9.33	8.18
2	12.55	12.51	12.50
3	12.60	12.60	12.56
4	12.64	12.65	12.59
5	12.66	12.66	12.61
6	12.66	12.68	12.65
	MEDIUM PI Soil		
Lime (%) Added	Medium PI Virgin Soil	Soil with 3% RCC - Hwy 31	Soil with 3% RCC -Hwy 75
	PH (ASTM C 977)		
0	8.49	9.77	8.99
2	12.41	12.44	12.41
3	12.45	12.50	12.46
4	12.51	12.50	12.49
5	12.51	12.52	12.51
6	12.52	12.53	12.52
Lime (%) Added	HIGH PI Soil		
	HIGH PI Virgin Soil	Soil with 3% RCC - Hwy 31	Soil with 3% RCC -Hwy 75
	PH (ASTM C 977)		
0	8.01	8.26	8.50
2	12.32	12.20	12.22
3	12.44	12.39	12.39
4	12.47	12.44	12.43
5	12.49	12.47	12.46
6	12.50	12.49	12.49

The University of Texas at Arlington defined the consistency of an unconfined soil (q_u) as very soft to very stiff as shown in figure 3. The soils tested in this study were found to be very soft as shown in Table 4.

Consistency	q_u (lb/ft^2
Very soft	0–500
Soft	500–1000
Medium	1000–2000
Stiff	2000–4000
Very stiff	4000–8000

Figure 3.

Figure 4. Failure pattern typical of brittle specimens.

Atterberg Limits (LL, PL, PI), percent retained on the #200 sieve, Maximum Dry Density and Optimum Moisture Content, and Unconfined Compression (q_u) tests were performed in order to evaluate the mechanical properties. These tests were performed on all soil mixture combinations proposed in this research and are provided in Table 4. It is observed that the addition of the 3% waste RCC had a minimal effect the LL, PL, and PI, Maximum Dry Density and Optimum Moisture content for all the soil types except for the High PI soils where the Optimum Moisture decreased 1 to 2 percentage points. When lime was added the LL, PL, and PI, and Maximum Dry Density and Optimum Moisture content results changed as would be expected. When evaluating the unconfined compressive strength (q_u) results with the addition of RCC and compared to the original soil, the key finding were found as follows.

KEY FINDINGS

The results show that the compressive strength of the soil with 3% RCC waste material did not cause a detrimental effect to soil modification. Figure 5. shows a typical stockpile of RCC fines produced from crushing operations. The Department of Roads has limited the amount of fines to be used as base course, due to potential drainage problems. When the concrete to be crushed is severely deteriorated the amount of concrete fines could be high; this may cause the Contractor to haul concrete fines to a landfill for disposal.

Figure 5. Recycled Crushed - Concrete Fines

Table 4.

Sample ID-Project	No.200 Passing Material	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index (PI) (%)	Moisture Density lb\ft^3	Optimum Moisture (%)	Unconfined (q_u) psi
		AASHTO T89	AASHTO T90		AASHTO T99		AASHTO T208
		Total averaged of four samples per testing					
	LOW PI SOIL						
Virgin Soil	92	30	16	14	110.2	15.3	184
Soil with 3% RCC - Hwy 31	89	30	16	14	111.3	15.2	215
Soil with 3% RCC -Hwy 75	89	30	16	14	111.3	15.4	212
Soil w/ 3% RCC - Hwy 31 and 2% lime	75	30	25	5	102.3	17.4	229
Soil w/ 3% RCC - Hwy 75 and 2% lime	73	32	25	7	102.3	17.7	227
	MEDIUM PI SOIL						
Virgin Soil	98	46	18	28	104.5	19.2	148
Soil with 3% RCC - Hwy 31	97	45	18	27	104.7	19.0	166
Soil with 3% RCC -Hwy 75	97	46	17	29	104.8	19.0	148
Soil w/ 3% RCC - Hwy 31 and 4% lime	58	37	30	7	95.3	21.3	154
Soil w/ 3% RCC - Hwy 75 and 4% lime	57	37	31	6	95.1	21.3	149
	HIGH PI SOIL						
Virgin Soil-	97	70	28	42	94.2	25.3	148
Soil with 3% RCC - Hwy 31	95	70	28	42	93.8	22.9	148
Soil with 3% RCC -Hwy 75	95	70	28	42	94.8	23.9	134
Soil w/ 3% RCC - Hwy 31 and 4% lime	33	44	39	5	91.5	27.0	159
Soil w/ 3% RCC - Hwy 75 and 4% lime	43	44	39	5	90.9	26.7	151

SUMMARY:

This study examined the use of Waste RCC for potential soil modification. The major findings in this evaluation were as follows:

- The addition of 3% RCC Fines did not change the amount of lime required for modification of the three soils tested.

- The 3% RCC Fines was found to be inert as either a stabilizer or a short-term modifier for all three soil types.

FOLLOW UP FIELD IMPLEMENTATION:

A limited field investigation should be performed to assess the in-situ performance of stabilized subgrades with the addition of RCC Fines. Based on the results to date, NDOR-Material and Research Division will allow an option to use up to 3% RCC fines in the subgrade. A comparison summary with estimated savings due to the addition of RCC fines will be evaluated and reported.