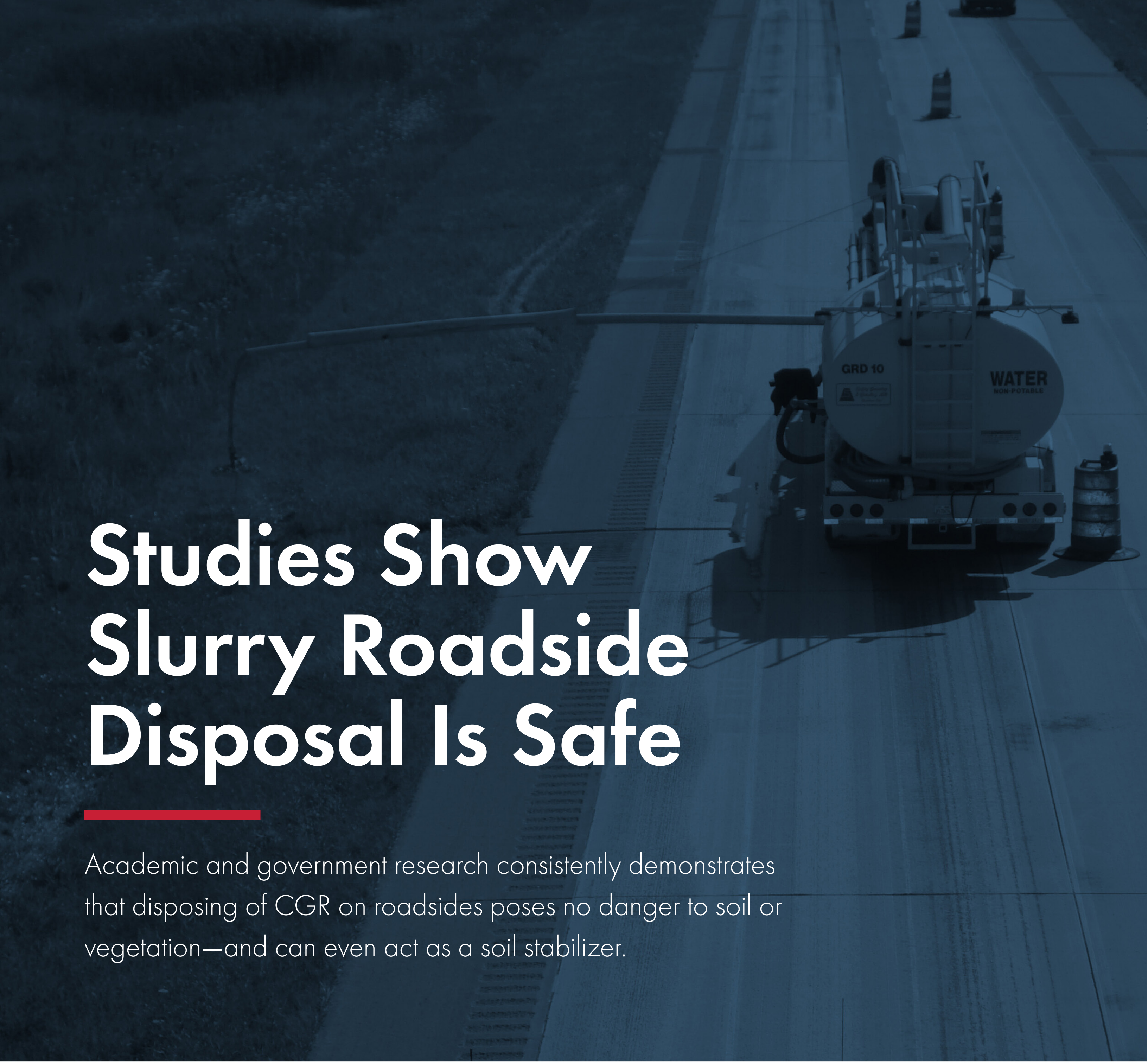

Studies Show Slurry Roadside Disposal Is Safe

Academic and government research consistently demonstrates that disposing of CGR on roadsides poses no danger to soil or vegetation—and can even act as a soil stabilizer.

Concrete grinding residue (CGR) is an inert, non-hazardous byproduct of the diamond grinding process, which is used on pavement to restore ride quality, increase skid resistance and reduce noise. When diamond grinding concrete highways, water used to cool cutting blades combines with hardened cement paste and aggregate particulates to generate CGR, also known as slurry.

IGGA
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MANY STATES DO NOT HAVE THE BENEFIT OF CLEAR, LOCALIZED GUIDANCE on disposal methods for CGR. This leads to a situation in which CGR disposal is potentially posing unnecessary costs for projects—and leaves the beneficial effects of slurry underutilized.

Often, states limit how much slurry can be discharged along the roadside during the diamond grinding process. But hauling slurry off-site for processing and disposal is costly for DOTs and for taxpayers. The elimination of unnecessary regulations in areas with site conditions that allow for the discharge of CGR directly to the road's shoulder would benefit roadway owners and taxpayers by reducing construction costs.

To determine the real impact of slurry on roadside soil and vegetation, multiple studies have been performed. They have all found slurry to be safe.

» WHAT IS SLURRY?

Slurry is a combination of water used to cool the grinding blades and solids resulting from the removal of a thin layer of the concrete, including silica, cadmium, and other chemical constituents of cement and supplementary cementitious materials. (It should be noted that while respirable silica on the jobsite can pose a health hazard to workers, silica in CGR is mixed with a substantial amount of water and does not become free or airborne after deposition on the site, so it is not harmful to workers.)

The contents of slurry reflect the contents of concrete—mostly mineral—as well as possible compounds present in the cooling water. Over the years, multiple laboratory tests have been conducted to identify the components of CGR. Per the criteria for identifying hazardous waste under U.S. Code of Federal Regulations, Title 40, Part 261, the elements and compounds present in tested slurry are non-ignitable, non-corrosive and non-toxic; therefore, CGR can be considered a non-hazardous waste.

Elevated soil pH has been the sole concern raised by slurry testing—and tests have shown the pH characteristics of disposed slurry did not exceed California's stringent Title 22 standards. The California Department of Transportation (Caltrans) found that slurry samples for organic and inorganic constituents displayed no hazardous characteristics when compared to California Title 22 hazardous waste standards. Caltrans 96-hour Acute Toxicity testing showed no toxicity characteristics and that the slurry samples represent no toxic threat to public health and the environment.

A Minnesota Department of Transportation (MnDOT) study found fresh CGR materials collected for research purposes were comprised predominantly of silica (53.12%) and lime (16.82%), which also are the major compounds found in concrete materials.

The lime (along with some trace minerals) found in CGR can be beneficial to plant life. In fact, many DOTs regulate the deposition of slurry in terms of its lime equivalency, often called calcium carbonate equivalency (CCE). Lime equivalency, expressed as a percentage, is the acid-neutralizing capacity of a carbonate rock relative to that of pure calcium carbonate (e.g., calcite).

ANALYZING SLURRY COMPOUNDS

In May 1990, seven samples of diamond grinding slurry were presented to an independent testing laboratory in Charlotte, North Carolina, for chemical analysis. The objectives of the analysis were to determine composition of the slurry, quantify each component, and compare volume to maximum permissible limits for each component as established by the U.S. Environmental Protection Agency (EPA) and the North Carolina Department of Environment, Health & Natural Resources (now part of the North Carolina Department of Environmental Quality [DEQ]).

The slurry samples were taken from three different work sites. One site had 20-year-old portland cement concrete (PCC) pavement; one site had two-year-old PCC pavement; and one site had one-year-old PCC pavement.

Two samples were obtained from three locations on a highway grinding project in Delaware; three samples were taken from different locations on an interstate highway grinding project in Pennsylvania; and two samples were taken from different locations on a bridge deck grinding project in South Carolina. These jobsites were selected because they were considered representative of most grinding work and because work was underway at the time samples were needed; the actual sample locations were selected at random and samples were obtained on different days.

After analysis, the report concluded:

> *Under the criteria for identifying hazardous waste under 40 CFR 261, the above waste is nonignitable, non-corrosive and non-toxic; therefore, it is generally considered a nonhazardous waste.*

» STUDIES FIND SLURRY IS SAFE

Researchers have been working to identify CGR's precise ecological effects, as well as how CGR disposal can be optimized. Tests consistently have shown that proper slurry deposition along roadsides is safe and can act like a fertilizer when used as a lime equivalent.

Let's review three studies by government and academic researchers—all of which found similar results.

MINNESOTA DEPARTMENT OF TRANSPORTATION AND IOWA STATE UNIVERSITY'S INSTITUTE FOR TRANSPORTATION

Beginning in 2016, Iowa State University (ISU) conducted the study, "Concrete Grinding Residue: Its Effect on Roadside Vegetation and Soil Properties," on behalf of MnDOT, evaluating slurry deposit impact on vegetation and soils. Tests included depositing slurry that had been collected from a slurry tank at a Minnesota construction site onto a controlled field site in Iowa.

CGR was applied to test sections of vegetation at rates of 10 tons/acre (2.24 kg/m2), 20 tons/acre (4.48 kg/m2) and 40 tons/acre (8.96 kg/m2); additionally, a control section was maintained. Properties of soils and plants were assessed before the application and one month, six months and one year after the CGR application.

Key Takeaways

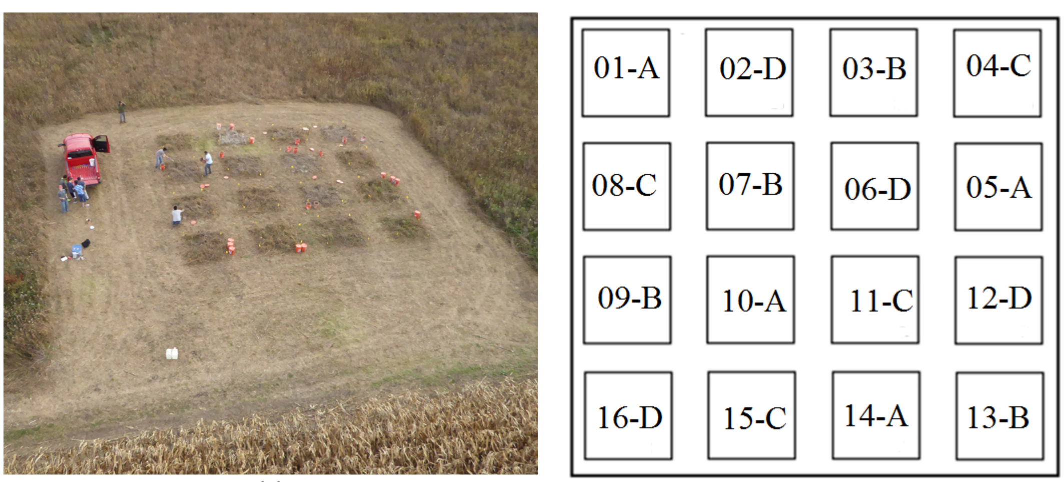
The study found that the application of CGR did not significantly affect soil physical properties. Effects of CGR on soil chemical properties were influenced by application rate, soil depth, time after CGR application and CGR source. Overall, application of CGR up to 40 dry tons/acre (the maximum amount studied) showed no significant adverse effect on soil or plant biomass.

IOWA STATE UNIVERSITY'S INSTITUTE FOR TRANSPORTATION AND IOWA HIGHWAY RESEARCH BOARD (IHRB)

Another study, "Use of Concrete Grinding Residue as a Soil Amendment," sponsored by the Iowa Highway Research Board (IHRB), further examined the environmental impacts of CGR. It also conducted a laboratory assessment of CGR as a soil amendment, since CGR's high pH and rich calcium oxide content make it potentially suitable for recycling as a soil stabilizer. Clayed sand (soil type A-6 according to the American Association of State Highway and Transportation Officials [AASHTO] Soil Classification System) and sandy, silty soil with clay (AASHTO soil type A-4) were studied, focusing on CGR's effect on soil plasticity and soil pH.

Results of the study demonstrated that as CGR content was increased, the A-6 soil's plasticity index (the difference between the liquid and plastic limit) decreased, going from an Atterberg limit measurement of 16 for the control group (with no CGR application) to a measurement of eight for the soil that received a CGR application rate of 40%.

For soil type A-4, Atterberg limit measurements decreased from seven (for the control group) to five (at the 40% application rate). The study also found that with the addition of CGR, the maximum dry density (unit weight) of the soil went down, while the optimal moisture content went up. Unconfined compressive strength and California bearing ratio (CBR) of each soil were found to be optimized at a 20% CGR content.



(a) (b)

*Aerial photographs showing the layout of the field test plots: **(a)** aerial photograph of the site and **(b)** layout of the CGR applications (numbers 01 to 16 are designated to sixteen plots; letters A, B, C and D represent the CGR applications rates of 0, 2.24, 4.48 and 8.96 kg/m2, respectively).*

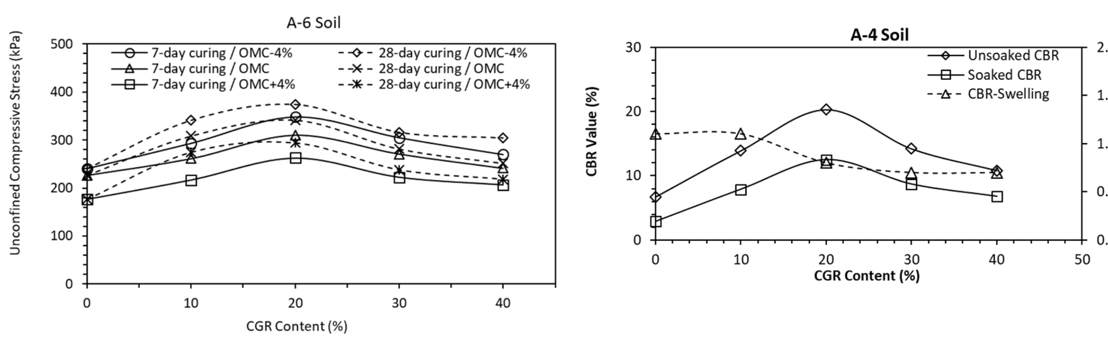
The application of CGR increased soil pH, alkalinity, electrical conductivity and cation-exchange capacity. Improvements in soil strength caused by the application of CGR are attributable to the formation of calcium silicate hydrate gel. The gel formation is a combined effect of flocculation, cement hydration and rehydration, and pozzolanic reactions. For the field investigation portion of the IHRB-sponsored research, the first application of CGR was made in the summer of 2020 and the second occurred in 2021. The objective of the field study was to strategize the field application process for CGR and evaluate its field performance in pavement shoulder stabilization.

To set up the first field study, two CGR-stabilized pavement shoulder sections (250 feet by 5 feet) were constructed in Washington County, Iowa. Two different CGR application methodologies were established:

1. A CGR reclaimed section, constructed by mixing settled CGR residue with the top 2 inches of shoulder materials; and

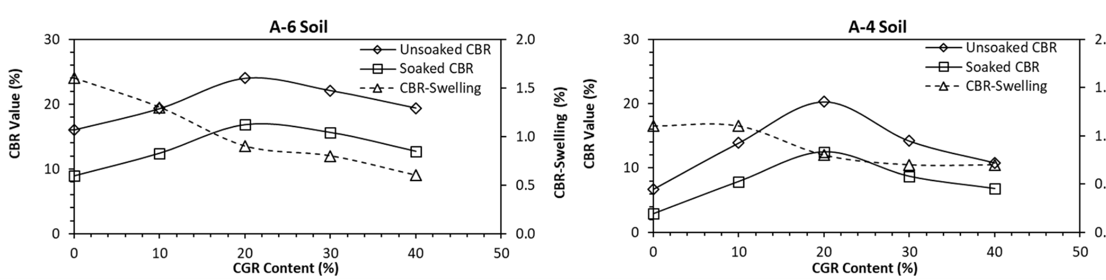
2. A CGR application on the top section only, constructed by placing a ½-inch layer of settled CGR on the pavement shoulder.

A section constructed with Base One (a soil stabilizing agent) was used as a control. CGR used in the test sections was collected at a diamond grinding site, then contained and transported in heavy-duty super-bags. CGR materials were allowed to settle in the bags before draining and dewatering.



(a) (b)

*Effects of CGR on unconfined compressive strength of **(a)** A-6 soil and **(b)** A-4 soil.*



(a) (b)

*Effects of CGR on California bearing ratio of **(a)** A-6soil and **(b)** A-4 soil after 7-day curing.*

Figure 1 below illustrates construction of a CGR site in Washington County. The team took advantage of the laboratory study results, using the 20% application rate that lab studies had shown to be optimal, to achieve maximum soil stabilization in their field testing.

__Fig. 1. (a)__ Mixing CGR with shoulder materials and __(b)__ compacted CGR amended pavement shoulder in Washington County.

(a) (b)

Researchers compared the performance of the Base One treated section to the "CGR on top" and "CGR blend" sections using a lightweight deflectometer (LWD). Results showed high elastic moduli after seven days for CGR-incorporated sections, with moisture playing a vital role in seven-day and 28-day moduli (weather was a factor in the test cycle, with a lot of rain occurring). Performance measures for CGR-treated sections were very similar to the section treated with Base One, indicating that CGR shows great promise as a soil stabilizer. Dynamic cone penetrometer (DCP) tests were also performed 28 days after CGR application. The CGR-reclaimed section had lower Dynamic Cone Penetrometer Index values, as well as the highest CBR values.

In May 2021, a second field demonstration site was constructed to explore the benefit of using CGR as a stabilizer for unbound pavement material at the shoulder. Located in Clinton County, Iowa, the site consisted of four test sections similar to those constructed in Washington County, including a Base One-treated section, a section in which CGR was mixed with shoulder material, a section that received CGR on its surface without reclamation and an untreated control section. Each section was 250 feet in length and 5 feet in width, and a 50-foot gap between sections was provided to avoid overlap between the sections during construction. The shoulder located on the other side of the road from the treated sections was considered an untreated section for field performance evaluation.

CGR was again collected and transported from a nearby diamond grinding operation and applied at a 20% rate to test sections. Field evaluation of the site was performed using LWD and DCP tests, as well as visual inspection. One year after construction, researchers observed that the stabilized sections had a lower loss of aggregate than the untreated section. It was hypothesized that CGR stabilization reduces aggregate loss from the shoulder of the road that is caused by wind generated by high-speed truck traffic.

Key Takeaways

Work performed by the Iowa State University's Institute for Transportation, when viewed alongside earlier study results from other states, allow researchers to conclude that, based on the soil types and plant communities investigated so far (with a maximum limit of 40 tons/acre), CGR roadside application poses no significant environmental drawbacks and may be beneficial in certain circumstances. CGR-stabilized shoulder sections may reduce aggregate loss.

NEBRASKA DEPARTMENT OF ROADS AND UNIVERSITY OF NEBRASKA-LINCOLN

Investigators from the University of Nebraska-Lincoln's Department of Agronomy and Horticulture prepared a report titled, "Evaluation of Concrete Grinding Residue (CGR) Slurry Application on Vegetation and Soil Responses along Nebraska State Hwy 31" for the Nebraska Department of Roads (now part of the Nebraska Department of Transportation). The study took place between 2012 and 2014 and evaluated the effect of CGR application on soil chemical properties, existing vegetation and rainfall runoff. Tests were conducted along two state highway sections, one consisting of loam soil and the other consisting of silt loam soil. The CGR effective calcium carbonate equivalent (ECCE) ranged from 13% to 28%.

Researchers took road shoulder slope measurements along NE State Highway 31, between mile marker (MM) 28 and MM36, to identify locations with uniform vegetation and adjacency to flat road areas. Sites selected for field experiments had an average slope of 21.3% for MM36 and 12.5% for MM34. Vegetation for all locations was predominantly cool season grasses. Soil textural classes were from loam to silt loam at both sites with pH greater than 7.0.

Slurry used for the MM36 experiment was collected in barrels from a diamond grinding operation in Grand Island, Neb., in October 2012 and stored in a temperature-controlled environment. Slurry used at the MM34 site was collected in a ready-mix truck from a diamond grinding operation in Elkhorn, Neb., in May 2013 and was transferred to barrels and similarly stored.

Prior to experimentation, all slurry was air-dried, mixed to homogenize and re-wetted to approximate water content on an actual diamond grinding operation. Using various methods, slurry density was estimated to be 10.3 lb gal-1 to 10.8 lb gal-1. Following EPA method 200.7, laboratory procedures were undertaken to determine:

- the moisture of the dried slurry to adjust application rate;
- the ECCE;
- the potassium, calcium, magnesium and sodium concentrations (percent by weight); and
- the heavy metal content (arsenic, cadmium, cobalt, copper, molybdenum, nickel, lead, mercury, selenium and zinc).

In July 2013, controlled slurry treatments were applied at MM36. The application rates of dry slurry (0% moisture) were 0, 4.1, 8.2, 16.4 and 32.9 tons/acre for each treatment. Multiplying by an average ECCE of 13%, slurry rates applied were converted to lime equivalent rates. These rates were 0, 0.5, 1.1, 2.1 and 4.3 tons lime equivalent/acre, respectively.

In June 2014, slurry treatments were applied along MM34. Application rates of dry slurry (0% moisture) were 0, 5.5, 10.9, 21.8 and 43.7 tons/acre for each treatment. With an average ECCE of 28%, the lime equivalent rates were 0, 1.5, 3.1, 6.2 and 12.3 tons lime equivalent/acre, respectively.

At both sites, dried slurry was mixed with water to achieve a density of 10.5 lb gal-1. Slurry was applied by hand.

Key Takeaways

For the 2013 and 2014 one-time CGR slurry application, no change was observed in runoff volume, runoff chemistry, ground cover or species composition. The highest CGR application increased soil sodium and pH in the short term (one month) but did not persist after one year of CGR application.

Nebraska currently disposes of CGR in accordance with the EPA's National Pollutant Discharge Elimination System Permit Program. According to the permit, CGR roadside application is restricted to 5 dry tons/acre. Test results demonstrated, however, that the 5 tons/acre limit may be too restrictive. The maximum rate of application during testing was 40 dry tons/acre. While this amount—eight times the current limit—did raise pH, calcium and sodium levels one month after application, testing after one year showed the higher CGR discharge rate did not have a significant negative effect on soil overall.

CONSEQUENCES OF ONE TIME CGR SLURRY APPLICATION EFFECTS BASED ON TWO SITE EXPERIMENTS,
with loam and silt loam soil textures, at NE State HWY 31 sites in 2013 and 2014

Property	Observed Change		Comments
	Yes	No	
Runoff volume		x	
Runoff chemistry		x	
Ground cover		x	
Species composition		x	
Soil pH	x		pH increased at 20 and 40 tons after one month but effect did not persist after one year.
Soil EC	x		Immediate increase that did not persist after one year.
Soil Ca	x		Ca increased at 20 and 40 tons after one month and effect was persistent after one year.
Soil Na	x		Immediate increase that did not persist after one year.
Soil K	x		Possible decrease due to excess Ca load.
Soil Mg		x	Possible decrease due to excess Ca load.
Soil heavy metals		x	Not measured but most are below threshold level in CGR slurry.

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Mamo, M., D. McCallister, W. Schacht, A. Wingeyer. 2015. Evaluation of Concrete Grinding Residue (CGR) Slurry Application on Vegetation and Soil Responses along Nebraska State Hwy 31. Final Report Prepared for the Nebraska Department of Roads (NDOR). NDOR Project #SPR-P1(13) M335)

Study authors recommended measurement of existing conditions and the development of field tests that will allow for adjustment of CGR application rates. They also caution that application rates must consider the ECCE, moisture of the CGR and roadside soil texture.

INTERNATIONAL GROOVING AND GRINDING ASSOCIATION AND NORTH DAKOTA STATE UNIVERSITY

In 2009, the International Grooving and Grinding Association (IGGA) entered a research project with North Dakota State University (NDSU). This research studied five CGR samples from different areas across the country. The samples were obtained from California Interstate Highway 10 (10/CA), Michigan Interstate 69 (69/MI), Nebraska Highway 75 (75/NE), Washington Interstate Highway 82 (82/WA) and Minnesota Interstate Highway 94 (94/MN). The research contained three phases:

1. Determine chemical composition and characteristics of CGR;
2. Determine what effect CGR has on the mechanical properties of the soil; and
3. Determine what effect CGR has on plant growth.

The chemical composition of the five CGR samples was analyzed with EPA methods 7470A, 6020A/6010B, 9038, 7196 and others. The tests were performed by a commercial laboratory. The CGR samples had a high pH, near 12. Otherwise, the solution phase levels reported were within toxicity limits outlined in the EPA's Code of Federal Regulations, Title 40, Part 261.

In the solid phase, mercury levels were below the reporting limit in four of the five samples, but one was elevated above what is expected in surface soils. Chemical oxygen demands ranged up to 2,210 mg/kg. Other solid phase values were below those generally found in surface soils. None of the semi-volatile compounds analyzed for were found in the samples.

The influence of CGR additions from two of the CGR sources on two different soil types was evaluated by infiltration experiments. One of the experiments involved spreading a 2.5 mm layer of CGR, which is equivalent to 14 tons of dry CGR per acre, on the soil surface prior to infiltration. Two other experiments consisted of mixing CGR with soil in the top 3 cm of the infiltration columns at rates of 8% and 25%, which is equivalent to 14 dry CGR tons and 43 dry CGR tons per acre.

This phase of the research initiative involved a greenhouse study looking at soil and plant health as a result of adding CGR. Samples 10/CA and 94/MN were air-dried and ground and mixed with two soils at rates of 8% and 25% by mass, which equated to 39 tons and 122 tons of dry CGR per acre, respectively. The two soils were a silty clay (fine, smectitic, frigid Typic Epiaquerts) and fine sandy loam (course-loamy, mixed, superactive, frigid Aeric Calciaquolls). Smooth brome (a common grass used for hay, pasture or silage) was planted into each treatment from seed and was used as the indicator of plant health.

At the termination of the experiment, a soil sample was taken, and plant and root biomasses were quantified. The soil and plant samples were sent to a private laboratory and analyzed for several parameters.

NDSU researchers were able to draw several conclusions from the CGR research initiative.

1. Soil pH and electrical conductivity will likely increase after CGR application due to the liming potential and total dissolved salts present in CGR.
2. Smooth brome growth will be a function of soil type, CGR, rate of application of this byproduct and, thus, CGR additions to soil will variably impact this plant species.
3. Uptake of calcium, an essential plant nutrient, by smooth brome likely will be accentuated by the application of CGR.
4. Trace metal uptake by smooth brome is variable and will depend on CGR and many soil chemical properties.
5. Soil application rates of CGR likely will not increase trace metal levels in either soils or smooth brome above those found in uncontaminated soils.
6. Application of CGR at the 8% rate (39 tons/acre) was beneficial for smooth brome growth, but application rates greater than 8% should be justified and are not recommended since the actual rate that smooth brome responded negatively was not determined.

Key Takeaways

This research indicates that CGR applied at less than 40 tons/acre, which is far more than is applied during normal grinding operations, is not harmful to the mechanical properties of the soil, increases the shoot biomass of smooth brome, and has a negligible effect on the trace metals in the soil and smooth brome. The addition of CGR does have a liming potential, which could be either good or bad based on soil type. It is recommended that good pH control measures should be a part of any CGR handling plan.

NDSU researchers determined the results of this study do not point to degradation of soil hydraulic properties as a result of CGR application overall. This presumes that longer filtration times are detrimental and speeding of infiltration is not. In most instances this is probably the case, but exceptions are possible. There was an indication that the changes in infiltration due to CGR may moderate with time.

Most importantly, the results of this work do not point to any reason, in terms of soil, chemical, physical or hydraulic properties, for restricting the application of CGR directly to soil when the application rates are less than those used in the experiments cited above.

» BEST PRACTICES FOR SLURRY MANAGEMENT

In accordance with research showing a lack of negative environmental effects from slurry disposal along roadways, states are changing regulations.

For example, Minnesota recently enacted legislation redefining their solid waste definition throughout the state, exempting concrete saw-cut slurry from the solid waste classification and allowing slurry to be spread along adjacent slopes. This was done in part because there was no evidence showing slurry constituted a threat to the environment.

IGGA determined best management practices for CGR disposal to help slurry byproduct continue to be handled in a professional, environmentally responsible way. When following the best management practices, studies show slurry is not harmful to soil or plant life and can even be beneficial as a soil additive.

SLURRY DISPOSAL

- In rural areas with vegetated slopes, slurry can be deposited on the slopes as the grinding operation progresses down the road. As part of the contract documents, the engineer identifies wetlands and other sensitive areas where slurry discharge operations are not permitted.
- The engineer and contractor do a site inspection before diamond grinding to identify sensitive areas.
- Spreading of slurry should not take place through sensitive areas.
- Spreading stop and start points should be clearly marked on the shoulder of the road.
- Slurry generated while grinding in unpermitted areas should be picked up and hauled for disposal in non-sensitive areas on the job.
- Slurry should not be allowed to flow across the roadway into adjacent lanes.
- Diamond grinding equipment should be equipped with a well-maintained vacuum system that can remove all standing slurry, leaving the roadway in damp condition after the grinder passes.
- The vacuumed material should be spread evenly on the adjacent slopes by dragging a flexible hose or other approved device along the slope.
- Spreading should not take place on the shoulder.
- Spreading should begin a minimum of 1 foot from the shoulder, with each pass of the grinder moving the spreading operation further down the slope to ensure no buildup of grinding residue.
- Slurry should not be spread within 100 feet of any natural stream of lake or within 3 feet of a water filled ditch. Efforts should be taken to restrict the spreading operation to above the high-water line of the ditch.
- At no time will the grinding residue be allowed to enter a closed drainage system. The contractor is responsible for providing suitable means to restrict the infiltration of the grinding residue into the closed drain system.

SLURRY COLLECTION AND POND DECANTING

- In urban and other areas with closed drainage systems, the slurry should be collected in watertight haul units and transported to settlement ponds constructed by the contractor.
- These ponds may be constructed within or outside the right of way. All locations should be approved by the engineer.
- Ponds should be constructed to allow for the settlement of the solids and decanting of the water for reuse in the grinding operation.
- At the completion of the grinding operation, the remaining water will be allowed to evaporate or may be used in a commercially useful manner, like dust control.
- After drying, the remaining solids may be used as a fill material, a component in recycled aggregate or any other commercially useful application.
- The pond area shall be reclaimed to its original condition and vegetated to protect against erosion.

SLURRY COLLECTION AND PLAN PROCESSING

- Slurry should be collected and hauled, as with pond processing.
- Various plant designs can be used, such as centrifuge and belt press.
- The plant site should be prepared to control any storm water runoff in accordance with state regulations.
- The site should be restored and vegetated at the completion of operations.
- The processed water and solids are to be handled in the same way as the settlement ponds.
- The site may be within or outside the right of way. Site locations are to be approved by the engineer.