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Defining Green

Evaluation of Potential pH Environmental Hazards and Mitigation Measures When Utilizing Recycled Concrete Aggregate in the Field

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By Mark Reiner, PhD, PE, PG, LEED AP™

Introduction

The United States national apparent consumption of construction sand and gravel increased by 1.6% from 2005 with a total demand of 1.28 billion tons in 2006 and a national per capita annual consumption of 9.6 short tons[1]. Recycled concrete aggregates (RA – this paper refers only to recycled concrete aggregates) can be infinitely recycled, thereby reducing the environmental and economic impact of extracting virgin sources required to meet this demand. In fact, the Federal Highway Administration's (FHWA) Recycled Materials Policy[2] stresses that recycled materials should get first consideration in materials selection and restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications. According to a recent FHWA study of RA use by state departments of transportation (DOT) in the United States,[3] 38 states recycle concrete as an aggregate base and 11 states allow recycled concrete as an aggregate source for new Portland cement concrete (PCC) paving. The overall findings of the study was that RA is a valuable resource, and by proper engineering it can be used as a replacement for virgin sources in any aggregate application.

Many DOTs have specifications for RA. For example, The Michigan Department of Transportation's (MDOT) use of RA is permitted by the Standard Specifications of Construction, and has constructed over 650 lane miles of PCC pavements using RA. The Minnesota DOT (MnDOT) specifications establish that RA can be used as coarse aggregate in PCC (section 3137.2 B) as well as aggregate for surface and base courses (section 3138.2 A). In fact, MnDOT and California DOT currently uses almost 100% of the concrete removed from its pavements as dense graded aggregate base. California DOT specifications allows for the base aggregate to be RA at any desired percentage. Despite being widely accepted, there is a legitimate environmental concern of elevated pH concentrations in limited applications of RA when utilized in saturated conditions, such as rip rap for bank protection or as base under permeable pavements or in saturated low-lying areas that have direct connection to local surface or groundwater systems. The concern being, that high pH values (basic) can be detrimental to the growth of bank vegetation and toxic for aquatic species, e.g. fish kill. However, as RA poses no risk of elevated pH runoff if incorporated into low- or impermeable materials, such as low-permeability structural fill or pavement, the perceived risk is often overstated due to the limited applications where this poses a concern and can be designed or mitigated to pose no significant environmental risk. This paper addresses the current DOT research into pH leaching from RA and the associated risks and mitigation measures to protect degradation of connected surface water and groundwater.

1 United States Geologic Survey (2007). The Mineral Industry of Colorado - Mineral Yearbook. Retrieved from http://minerals.usgs.gov/minerals

2 http://environment.transportation.org/environmental_issues/construct_maint_prac/compendium/manual/5_7.aspx

3 FHWA - Transportation Applications of Recycled Concrete Aggregate: FHWA State of the Practice National Review, September 2004

RA Potential for Environmental Impact

The United States Environmental Protection Agency (EPA) mandates that pH from storm water runoff maintain a range between 6.0 to 9.0 standard units[4] as part of the Clean Water Act. The high pH from RA runoff results from the residual cement paste that can release high concentrations of free hydroxyl ions (OH-) when exposed to water. Several laboratory tests have been performed by State DOTs on the runoff from RA. However, because stream flow conditions and baseline water quality parameters in the field vary tremendously from laboratory tests, these tests are not subject to the same reaction with the atmospheric CO_2 and do not replicate water flow conditions at a field site. As a consequence, the pH values obtained in the laboratory analysis would not be the same as those expected in the field.

Ohio Department of Transportation (ODOT): ODOT conducted box tests to evaluate the change in pH from RA runoff during exposure to storm events.[5] De-ionized water was recirculated through 10 lb samples of RA for 40-days with initial pH results mostly above 11 and decreased rapidly to the 10 to 10.5 range before leveling off in the 9 to 10 range. From these box tests, the conclusion was stated *"..., using recycled concrete materials as an aggregate base in low lying or wet areas where alkaline run-off would be likely to occur could have an adverse effect on the environment.*" However, this conclusion did not address any potential for mitigation along the pathway from RA to local waters and only provided pH results applicable for water in continual direct contact with RA. Therefore, the tests do not provide guidance for contamination to surface water or groundwater.

Iowa Department of Transportation (Iowa DOT): Iowa DOT performed a one-year long box test with slightly different methodology. Distilled water was allowed to soak the RA for the initial 24-hours before being drained. After seven days, 17 oz (500 ml) of distilled water was poured into the upper end of the box and drained at the lower end and pH measured. The seven day cycle was repeated for one year.[6] Again, the elevated pH was around 11 standard units and the pathway of direct continual contact to RA is similar to that of ODOT's test, but with a longer period of dry aggregate. Appropriate mitigation measures were not discussed.

Minnesota Department of Transportation (MnDOT): MnDOT measured runoff pH from stockpiles of fine and coarse RA and reported median pH values of 9.3 and 9.8, respectively, both exceeding the Minnesota standard of 8.5 for surface water quality for fishing and recreation. The conclusion reached from this study stated *"This may not be a major problem. The pH of natural rainfall is in the range of 5.2 to 5.4 and surface flowing rainwater may have sufficient acidity to neutralize alkaline runoff from the stock piles before it reached surface waters."*[7] Although this includes some qualitative discussion on natural mitigation, the conclusion also states that more research is required to provide guidance on the effect of time of transport and the possible impacts on local water systems due to factors such as: depth to water table, permeability of soils and depth, lithology and permeability of the bedrock, and time of transport. The guidance simply recommended that possible planning for stockpile storage sites should include management practices of controlling runoff similar to those that are used for construction sites; berms, straw bales, grass or other filter channels.

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4 40 CFR § 133.102 Secondary treatment (c)

5 Ohio Department of Transportation (ODOT) – Office Of Materials Management: "Recycled Portland Cement & Concrete/Soil Mixtures and pH", February 2002

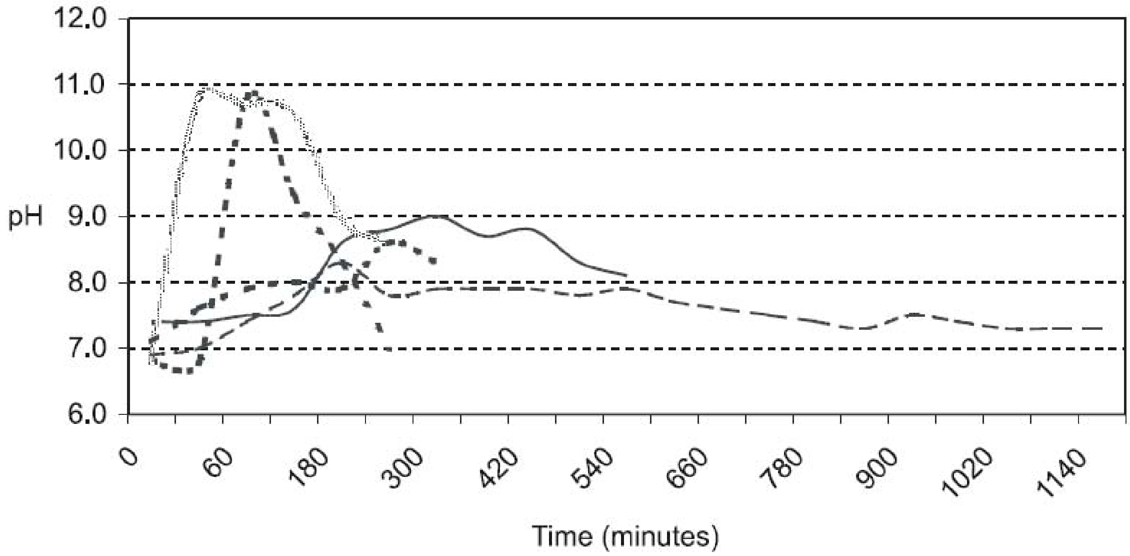
6 Steffes, Robert – Iowa Department of Transportation "Laboratory Study of the Leachate from Crushed Portland Cement Concrete Base Material: Final Report" September, 1999

7 Sadecki, Roger, et al – MnDOT "An Investigation of Water Quality in Runoff from Stockpiles of Salvaged Concrete and Bituminous Paving", September 1996

MnDOT also investigated the effect of RA as a base when adjacent to longitudinal drains and geofabrics are specified. Experience had found that if the longitudinal drain was enveloped with a geofabric, the dust and Ca(OH)2 precipitate, particularly from the fine fraction of RA, will collect on the surface of the geofabric and cause reduced efficiency of the drain. This study found that simple placement of the geofabric was enough to mitigate any negative effects, as discussed in the next section.

Virginia DOT (VDOT): VDOT performed likely the most comprehensive test that provided actual mitigation recommendations as to the effects of elevated pH on surface water quality. Using in-field conditions, VDOT monitored 31 sites for pH increases from grout containing Portland cement. As Portland grout is the primary source of OH- ions in RA, this field study is considered appropriate for determining proper mitigation measures. The study found that pH increases typically occurred within several minutes of the commencement of grout pumping, but varied from site to site due to local water and baseline water quality conditions. The results found that, with respect to dilution, the pH of the water declined only slightly at the downstream monitoring stations, indicating that dilution or dispersion of the high pH plume did not occur to any significant extent. With respect to time, the decline of the pH readings varied from 1.5 to 4.6 hours following the completion of the concrete placement, as shown on Figure 1.[8] Those sites where the greatest quantity of concrete was placed did not have the highest total rise in pH, but the pH took a longer time to return to baseline conditions.

Figure 1: pH Values with Respect to Time (Source with permission: VDOT, 2003)



Although runoff from RA will produce elevated pH levels, mitigation of these effects can be engineered with proper guidance. The ODOT, MnDOT and VDOT studies did provide interesting mitigation guidance for using RA when in contact with surface water, as discussed in the next section.

Mitigation of pH from RA in Environmentally Sensitive Areas

As previously mentioned, RA is widely accepted for bank stabilization, as well as a road base and an aggre-

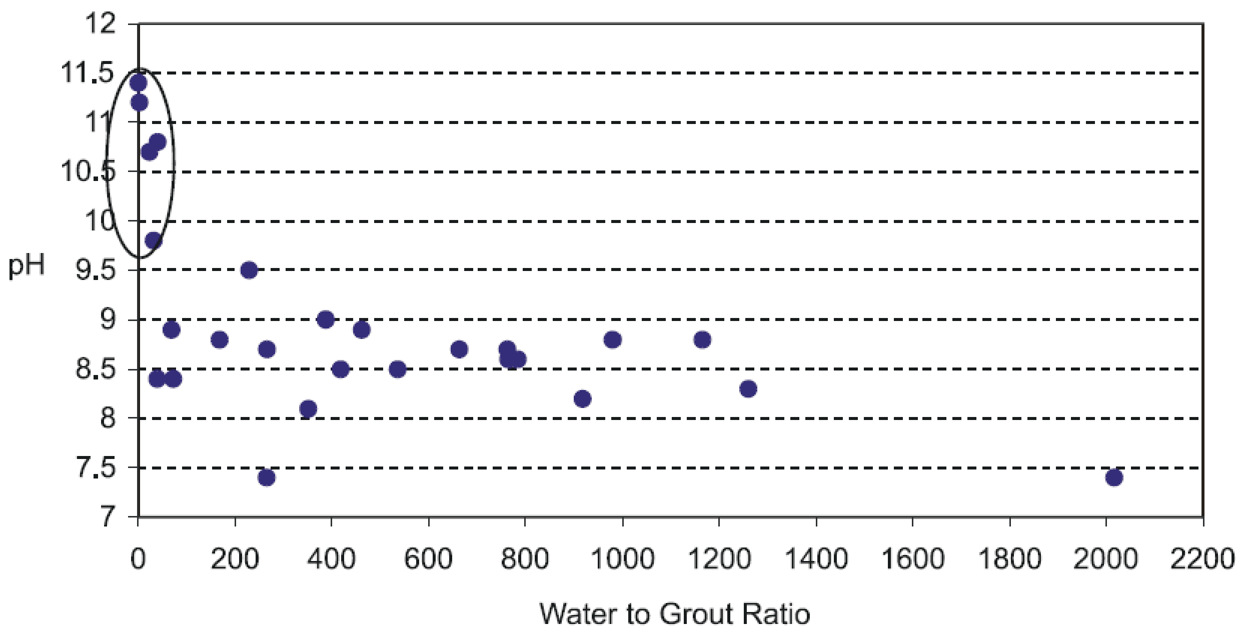
8 Fitch, Michael - Virginia Transportation Research Council "Final Report: Minimizing the Impact on Water Quality of Placing Grout Underwater to Repair Bridge Scour Damage", in cooperation with the U.S. Department of Transportation Federal Highway Administration Charlottesville, Virginia June 2003

gate source for new PCC. This section discusses the mitigation measures needed for RA placed into environmentally sensitive areas. In all cases, a project in an environmentally sensitive area should evaluate the local water quality standards and the potential pathways by which the risks of elevated pH may have some deleterious environmental impact. The following general recommendations are results of the DOT studies and should be used as general guidelines.

ODOT: Results from the ODOT *Bucket Test* indicate that blending a limestone aggregate source with RA at a ratio of 60% (or more) to 40% (or less), respectively, will result in runoff water with a pH less than 9 which is acceptable.[9]

VDOT: From the field data collected, VDOT determined that total stream flow is one of the most critical factors influencing the rise in pH resulting from RA (or concrete grout).[10] In high volume streams, the pH values only increased by 0.3 pH standard units above baseline conditions. However, in low-volume streams, pH values exceeding 11.0 were recorded at downstream stations before returning to baseline values in 4 to 6 hours after grout placement was completed (See Figure 1). One of the more useful results from this study is that VDOT provided guidance on grout (RA) placement in water based on the pH data collected with regard to stream flow. The conclusion was that it is safe to assume that with a 60:1 water to concrete (RA) ratio would keep in-stream pH values below 9.0 for streams with a baseline pH of 8.0 or less. A summary of these data are shown on Figure 2.

Figure 2: pH at Various Water to Grout Ratios (Source with permission: VDOT, 2003)



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9 Mulligan, Sean – Ohio Department of Transportation – Office of Materials Management "Report Recycled Concrete Materials" June 14th, 2002

10 Fitch, Michael - Virginia Transportation Research Council "Final Report: Minimizing the Impact on Water Quality of Placing Grout Underwater to Repair Bridge Scour Damage", in cooperation with the U.S. Department of Transportation Federal Highway Administration, Charlottesville, Virginia June 2003

MnDOT: In addition to recommending best management practices for RA stockpile storage guidance (e.g. berms, straw bales, grass or other filter channels, and locating stockpile sites some distance from surface waters), MnDOT provided guidance for RA as a drainage layer. The report claims that when utilizing RA for drainage layers, a blend of RA with new aggregate may be used as subgrade when at least 95% of the RA is retained on the 4.75 mm sieve. RA may be used up to 100% in construction of the filter/separation layer under a permeable aggregate base drainage layer in accordance with the applicable drainage specifications.

For concerns of RA precipitation and filter fabrics, MnDOT reported the proper design is to not envelop the fabric, but to leave the top open (U cross-section) to allow entrance of water into the longitudinal drain without the need of water only being able to flow through the fabric. The fabric is still available to prevent the intrusion of the subgrade fines into the drain but not to filter the water flowing into the drain from the base itself. This design precludes a drainage failure due to surface coating of the geofabric.

Conclusion

Applications where run-off may be of concern only represent a small fraction of the uses for RA. As previously mentioned in the MnDOT study, the pH of natural rainfall is in the range of 5.2 to 5.4 and rainwater may have sufficient acidity to neutralize alkaline runoff from RA before it reaches surface waters. Although dilution is not an accepted method of treatment, the actual potential for RA runoff to have any detrimental effect on the body of water needs to be considered and the volume of the body of water and pathway are critical factors to this assessment. In addition to neutralization by rainwater, the impact of soil buffering and equilibrating with atmospheric carbon during the time of transport from a RA source to local waters will ultimately determine the hazard, if any, for a potential project. Such studies could address a safe distance from receiving water bodies relative to the volume and surface area of the RA source.[11] Construction projects faced with environmental risk assessment of using RA would benefit by more study done on mitigation measures to avoid more complex assessments to be cost-effective.

Laboratory tests should be developed to simulate in-field conditions and report mitigation measures. Reporting results without cause-and-effect relationships can lead to generalizations about RA utilization, where incorporating RA into nearly any project will not have any adverse environmental effect and the rest of the applications can be appropriately mitigated. The bottomline for RA is that only positive environmental impacts result from specifying RA as landfilling of this material is avoided.

11 Sadecki, Roger, et al – MnDOT "An Investigation of Water Quality in Runoff from Stockpiles of Salvaged Concrete and Bituminous Paving", September 1996

About the Author

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Mark has been a Project Engineer and Design Engineer on a variety of governmental and private sector projects including the design, construction-related engineering, and review of superfund projects, water storage reservoirs, dams, and various geotechnical projects. He currently serves as an Adjunct Faculty at the University of Colorado at Denver and Health Sciences Center where he teaches a course on Urbanization in Developing Countries and conducts research related to a technology, environment, resource, and policy assessment of sustainable concrete in urban infrastructure. Mark has extensive international experience as the former Projects Director for Engineers Without Borders – USA and as Co-Lead on developing sustainable scenarios for the master infrastructure plan for Kigali/Rwamagana, Rwanda.

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