Guidelines for Handling Acid-Producing Materials on Low-Volume Roads

THOMAS W. FENNESSEY

In certain geologic formations, the use of conventional excavation and embankment construction techniques may result in acid runoff (pH $\leq$ 4.5). In turn, this may contaminate nearby streams and severely impact the fauna and flora that live in those streams. Acid runoff is most likely to be produced by the weathering of rock materials containing sulfur mineralization in excess of 0.5 percent that do not contain sufficient alkaline mineralization to neutralize the resulting acid runoff. Often, low-volume roads are constructed in environments where live streams and wildlife exist close to the construction right-of-way. Accordingly, environmental impact of the construction of low-volume roads on the adjacent lands is of great concern. Guidelines are presented that have been developed and implemented on existing low-volume roads to minimize the impact that the handling of acid-producing materials has on the adjacent environment.

As encountered in conventional roadway excavation and used herein, acid-producing materials are defined as those materials which, when exposed to the weathering process, produce acid runoff having pH values of 4.5 or less. Typically, it is the fresh exposure of unweathered rock that creates the potential for acid runoff. Soil, as a product of the decomposition and leaching caused by the weathering process, does not normally pose a threat to produce acid runoff unless the soil still contains a significant amount of undecomposed rock particles.

Rock materials most susceptible to producing acid runoff upon weathering are normally those that contain 0.5 percent or more of sulfur mineralization and that do not contain sufficient alkaline mineralization to neutralize the resulting acid runoff. The sulfur mineralization is most commonly found in the form of pyritic sulfur. The sulfur mineralization can be found in both venous and disseminated form.

Potentially acid-producing geologic formations are found in all three classes of rock; sedimentary, metamorphic, and igneous. However, the most common acid-producing materials occur as sedimentary and metasedimentary deposits such as carbonaceous shale and argillaceous deposits that have little or no neutralization potential. Sulfur mineralization can also be found in coarser textured sandstone and metasandstone. The presence of sulfur mineralization within these materials is generally attributable to the anoxic environment under which the sediments were deposited (*1*).

The darker color commonly associated with carbonaceous materials may serve as an indicator of potentially acid-producing mineralization. However, it is not a sure indicator. All materials in a geologic formation deposited under an environment conducive to the formation of sulfur mineralization should be suspect.

FHWA, Eastern Federal Lands Highway Division, 21400 Ridgetop Circle, Sterling, Va. 22170.

Currently, laboratory testing methods have been established to determine the acid-producing potential of a suspect material (*2*). The methods evaluate the acid-producing potential and the neutralization potential of a material in terms of equivalent tons of calcium carbonate per 1,000 tons of material. The result is commonly expressed as the net neutralization potential. A material having a net neutralization potential of 5 tons or less (a net acid-producing potential of 5 tons or more) is considered to be capable of producing environmentally harmful acid runoff. This material, therefore, requires special handling and treatment during excavation and embankment construction to minimize the impact on the adjacent environment.

In reality, the process of handling acid-producing materials begins well in advance of, and extends well beyond, construction itself. It is best expressed as a four-phase process—

- Preliminary design,
- Final design,
- Construction, and
- Postconstruction.

The process discussed involves expenditure of significant effort with an increased cost to the project. However, the purpose of this process is to avoid the additional cost to the environment and public opinion or perception associated with damage to environmentally sensitive areas adjacent to low-volume roads.

PRELIMINARY DESIGN

The first phase of this process focuses on determining whether or not acid-producing materials underlie the proposed roadway corridor. This phase begins with examination of available geologic references regarding the type and character of the rock formations that underlie the project site. Chemical analysis of the rock materials presented in geologic references may provide a quick assessment of the acid-producing potential of the rock formations.

Examination and sampling of exposed outcrops should also be done along the proposed corridor. These samples, along with rock core samples from a preliminary subsurface investigation, should be tested to determine the net neutralization potential of suspect materials. Geologic stratigraphy and structure should be noted to determine whether potentially acid-producing materials may only be encountered at certain elevations or limited areas along the project. At this stage in the project, it is important to be flexible to consider an alignment shift (vertical or horizontal) or an alternate alignment corridor to reduce, or avoid, exposure of acid-producing materials.

FINAL DESIGN

If acid-producing materials are indicated to underlie the project corridor during the preliminary design phase, additional steps will be required during the final design phase to address and prepare for the handling of the materials. The first step to be undertaken is the implementation of a water quality monitoring program. The accumulation of a set of baseline data, with regard to water quality in adjacent streams and ponds, is a time-consuming, yet essential item. Once established, the water quality monitoring program will be a continuing activity through the construction and postconstruction phases in the process of handling acid-producing materials.

It is also recommended that a more detailed subsurface exploration be performed to more accurately define the location and amount of acid-producing materials that will require special handling techniques. It is readily apparent that the subsurface exploration program should examine the materials to be encountered over the full depth of excavation at proposed cut locations. It may not be so readily apparent that the subsurface exploration program should also examine the materials to be encountered at proposed fill locations where excavations will be made for fill benching. The use of conventional rock core drilling in subsurface exploration can be supplemented with the use of air drills. A composite sample of the cuttings from the air drill excavation can be obtained. These samples, as well as rock core samples from additional rock core drilling, should be chemically tested to determine the net neutralization potential of the materials.

Another tool to be used in the detection of rock containing sulfur mineralization is induced-polarization (IP) resistivity surveys (*3*). The basis of this technique uses the response characteristics exhibited when an electric current passes through a subsurface zone of mineralization. IP resistivity surveys can be used to provide a more continuous subsurface exploration method to examine the entire alignment as a supplement to a rock sampling and testing program. However, the IP resistivity survey technique must be calibrated with knowledge of the geology and chemical testing of rock samples because IP resistivity surveys cannot distinguish between the presence of sulfur mineralization and the presence of other good conductors such as graphite. In addition, the induced polarization survey acts only as a method to detect potential acid-producing mineralization and cannot assess the neutralization effects of alkaline mineralization in the same rock formation.

IP resistivity surveys can be run as both reconnaissance and more detailed subsurface exploration tools. Thus, the line interval, electrode interval, and electrode configuration must be chosen with a specific purpose in mind (*3*). For example, in a reconnaissance survey, an electrode interval of 200 ft with a single line interval may be desired, whereas for a more detailed survey, an electrode interval of 25 ft with multiple line intervals may give better resolution and detection of smaller mineralization deposits. The depth and width of the proposed cuts should be considered in setting the configuration of the IP resistivity survey.

The results of induced polarization resistivity surveys are commonly expressed in terms of percent frequency effect (PFE), metal factor (MF), and resistivity (R). Establishment of threshold values of PFE, MF, and R that correlate with the presence of acid-producing materials and the resulting net neutralization potential should be established for use on each project. Suggested threshold parameters (*1*) include—

- PFE values greater than 10 percent generally indicate high concentrations of polarizable mineralization,
- MF values greater than 1 generally indicate easily weathered polarizable mineralization, and
- R values less than 10 000 ohm-m generally indicate easily weathered materials.

These parameters should be compared with the results of chemical analyses of available rock samples. However, good correlation may not occur for the reasons indicated previously.

As the more detailed information on the location and extent of acid-producing materials along the alignment corridor becomes available, it is again time to evaluate whether it is appropriate to use an alignment shift or grade change to avoid or minimize excavation of acid-producing materials. It should also be pointed out that significant alignment changes at this point will likely warrant additional subsurface exploration.

Once the final alignment is determined, the quantity of acid-producing materials requiring special handling must be determined from project cross sections. For ease of construction, it may be determined to be more cost-effective to consider all materials from an entire cut area, including soil overburden, to be acid-producing rather than require selective excavation and handling by the contractor. Prudent design also includes providing a percentage of excess volume in the quantity of acid-producing materials as a factor of safety to accommodate additional small quantities of such materials not identified during the subsurface exploration process.

Once the quantity of acid-producing materials requiring special handling is determined, the method of handling these materials must be designed. Any effective handling method must achieve one or more of the following (*1*):

- Control oxygen,
- Control water,
- Promote alkalinity,
- Control acidophilic bacteria, and
- Remove sulfides.

Currently, encapsulation of the acid-producing materials is the favored method. Encapsulation seeks to eliminate groundwater flow through the acid-producing embankment materials by providing drainage provision beneath the fill. Encapsulation seeks to provide excess alkalinity by the inclusion of neutralizing materials within the acid-producing materials. Finally, encapsulation seeks to cap the acid-producing materials to cut off the infiltration of air (i.e., oxygen) and water into the fill, preventing formation of the proper atmosphere for the production of acid runoff.

Based on the design method employed and the amount of acid-producing materials to be encapsulated, the amount of materials to be used in the encapsulation process must be quantified. Sources for these encapsulation materials must be located and identified. Provisions must then be made to locate and design the individual sites for the encapsulation of the acid-producing materials. The encapsulation sites can be located either on-site or off-site in embankment or side-hill fill locations. The sites should be selected to minimize haul distances of the acid-producing materials and the encapsulation materials.

Drainage is another area of special concern in the final design phase. Surface water should be directed away from cut slopes in acid-producing materials and away from encapsulation sites. Paved waterways should be used in the ditches above encapsulation sites to minimize infiltration. Curbing can also be used at the edge of pavement above encapsulation sites to reduce sheet flow down the face of the slope and further minimize infiltration. Ditches below cuts in acid-producing materials should be paved or limestone lined to act to neutralize minor acid runoff. Encapsulation sites should be selected to avoid high groundwater or stream flow locations.

In order to minimize the surface area of acid-producing materials exposed in cut sections, it is recommended that cut slopes in these materials be made as near to vertical as possible. On the other hand, the slopes of acid-producing fill materials and the encapsulating materials that cover them should be designed with a conservative factor of safety against slope stability failure. Where cut or fill slopes 1.5H to 1V or flatter are used with acid-producing materials, the slopes should be capped with soil, seeded, and mulched.

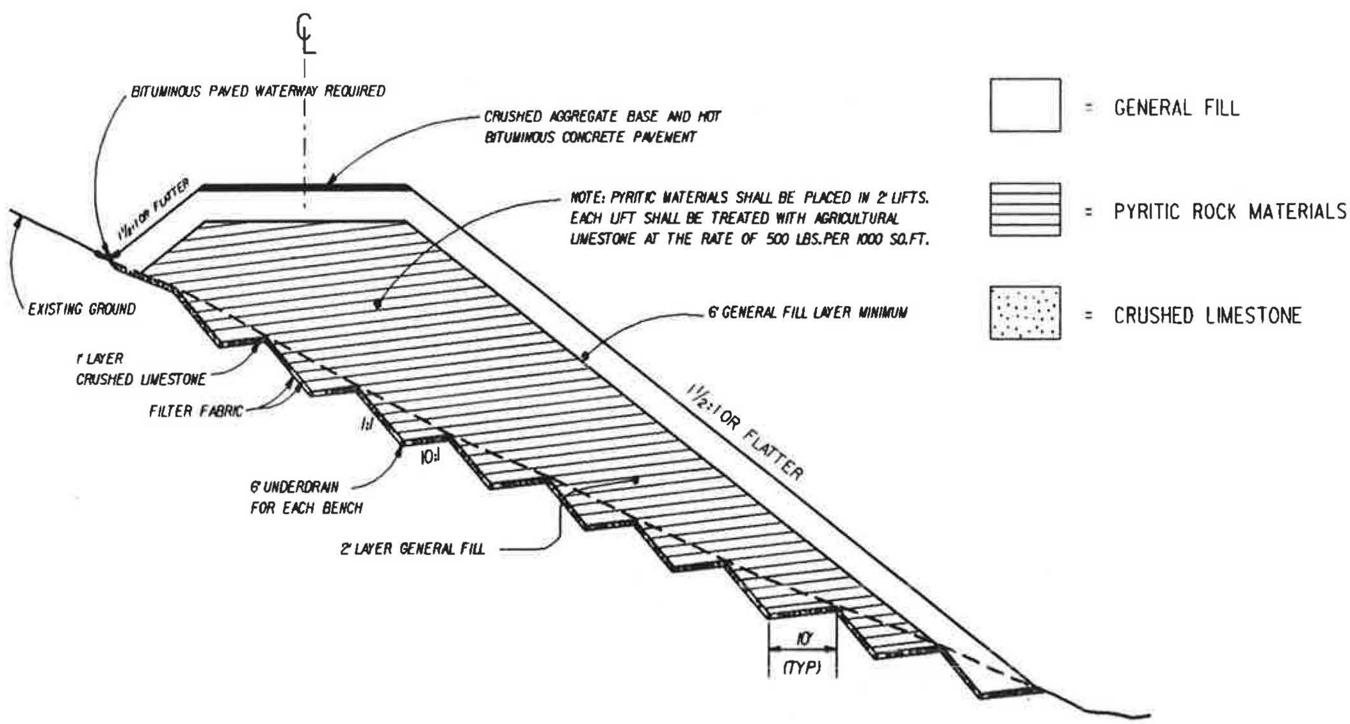
An encapsulation design employed for the past several years by the Federal Lands Highway Division of the FHWA on several low-volume road projects on U.S. Forest Service land is shown in Figure 1. The design calls for the placement of a 12-in.-thick drainage blanket of crushed limestone (AASHTO M43 No. 57 stone) bound top and bottom with a layer of filter fabric against the benches at the back and base of the fill slope. Six-inch underdrain pipes are incorporated into this drainage blanket at the back of each fill slope bench. Acid-producing materials are then placed in 2-ft-thick compacted lifts. Each lift is treated with 500 lb of agricultural lime per 1,000 ft^2. The encapsulation site is then covered with a 6-ft thickness of compacted soil (AASHTO Classification A-4).

On a recent project where limited quantities of on-site cover materials were available, this design was modified to reduce the thickness of the limestone drainage blanket and the soil cover by 50 percent to 6 in. and 3 ft, respectively. Evaluation of field tests simulating this modification indicates acceptable results (*1*). Monitoring of the actual installation is ongoing.

CONSTRUCTION

The most important element in the construction phase of this process is that the contractor and construction project engineer both be familiar with the known locations of, and procedures for, handling acid-producing materials. The contractor must be familiar with special handling provisions to efficiently schedule the work to promptly transport and place acid-producing materials in a designated encapsulation site as encountered. Unnecessary handling and storage of acid-producing materials should be minimized.

In addition, as materials are excavated, they should be examined to verify or detect the presence of sulfur mineral-



BURIAL AREA IN FILL

FIGURE 1 Method for treatment of acid-producing material.

ization during construction. In the field this should be done at least visually by a trained inspector. Any questionable material can be temporarily covered with plastic film or treated with lime until results of chemical testing are available to determine the appropriate final handling of the material. As a supplement to the visual inspection, composite samples of rock materials from air drills can be routinely obtained and chemically tested in advance of the excavation to aid in detecting any changes in the anticipated handling procedures. During construction, it is also critical to monitor and compare the actual versus estimated volumes of acid-producing materials coming from the cut areas. The values must be compared to determine if sufficient encapsulation site volume is available for the remainder of the project.

An ongoing program of water quality monitoring should already be in place at the time of construction. The frequency and location of such monitoring should be increased as construction is underway in an effort to quickly detect and correct any problems as they occur. The monitoring program should be structured in such a manner that water quality sampling frequency is tied to local precipitation events and not to a strict sampling schedule.

POSTCONSTRUCTION

The encapsulation method discussed previously has performed satisfactorily for the past several years and is considered to be a proven method. However, studies have shown that, even after 10 years of exposure, acid-producing materials are still capable of producing significant acid runoff (*1*). Thus, while the handling of the acid-producing materials are still capable of producing significant acid runoff (*1*). Thus, while the handling of the acid-producing materials ends with construction, the water quality monitoring program may be continued for a period of time to assess the postconstruction performance of the encapsulation and special handling design features. This is particularly encouraged where modifications or new methods of handling acid-producing materials are employed. The postconstruction water quality monitoring program can also include monitoring of discharge from drainage blankets beneath encapsulation areas and drainage in ditchlines below exposed cuts in acid-producing materials. As noted previously, such a monitoring program should be structured in such a manner that water quality sampling frequency is tied to local precipitation events and not to a strict sampling schedule.

REFERENCES

1. D. W. Byerly. *Guidelines for Handling Excavated Acid-Producing Materials*. FHWA-DF-89001. U.S. Department of Transportation, 1989, 82 pp.
2. A. A. Sobek, W. A. Schuller, J. R. Freeman, and R. M. Smith. *Field and Laboratory Methods Applicable to Overburdens and Mine Soils*. EPA-600/2-78-054, U.S. Environmental Protection Agency, 1978, 214 pp.
3. D. H. Jones, B. S. Bell, and J. H. Hansen. The Application of Induced Polarization in Highway Planning, Location and Design; *Proc., 32nd Annual Highway Geology Symposium*, Gatlinburg, Tenn., 1981, pp. 154–173.