Geosynthetics, J. Kuwano & J. Koseki (eds)
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Long term monitoring of alkalinity at the geogrid-block interface at a full scale masonry block retaining wall

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Keywords: retaining wall, masonry blocks, segmental regaining wall, alkalinity, polyester, geogrid, geotextile, geosynthetic, pH-measurements, degradation, durability,

ABSTRACT: The use of masonry block walls reinforced by geogrids or geotextiles is arguably the fastest growing segment of geosynthetics. Due to their excellent aesthetics, low costs, easy constructability, and good performance, these structures are seen throughout the world. They are called segmental retaining walls (SRWs) in North America and form a major part of mechanically stabilized earth (MSE) walls in a geotechnical engineering sense. When the geogrid or geotextile reinforcement is made from polyester (PET) resin, a concern over durability with respect to high alkalinity is sometimes expressed. The focus of this paper is to present field data from a PET geogrid reinforced masonry block wall which was built using three different block types. The wall is 14.3 m long and 2.4 m maximum height and serves the purpose of replacing a failed timber wall. Alkalinity (as measured by pH) measurements are being taken directly between the block surfaces at the contact of the geogrids to the masonry block units. Data for the first two years of monitoring is presented and shows a gradually decreasing trend, currently at or below pH = 8.5, with about 1.0 pH-unit separating the behavior of the different block types.

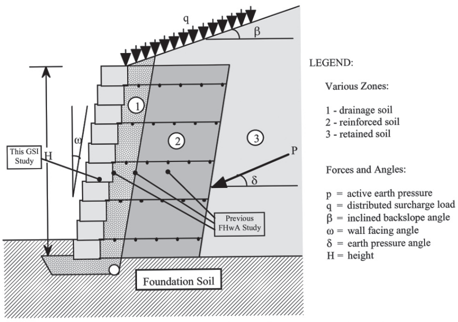
1 BACKGROUND

In constructing a masonry block retaining wall, it is imperative to use both durable masonry units and reinforcement. Typical service lifetimes are on the order of 100 years. Most masonry block units are manufactured of high compressive strength (greater than 20 MPa) and low adsorption concrete (maximum 9% per ASTM C1372) which helps make them resistant to spalling, scour, abrasion, rot, and the effects of freeze-thaw cycles. Spaced between and within the masonry block units is the geosynthetic reinforcement which is predominantly geogrids for this application.

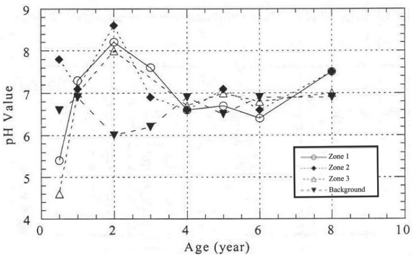
In this regard, the polymers used for the reinforcing geogrids are made from either polyolefins (polyethylene or polypropylene) or polyethylene terephthalate usually referred to as polyester, or simply PET. The degradation of these polymers is very different. Polyolefins are sensitive to thermo-oxidative degradation, while PETs are sensitive to hydrolytic degradation. In the latter case, which is the subject of this study, the alkalinity of the liquid is an issue. Furthermore, at either the very low or very high ends of the pH-scale the degradation becomes progressively more severe.

There have been numerous laboratory studies performed in regard to the long-term degradation of the above mentioned polymers (Anderson, et al. 1992, Jailloux and Verdu, 1990 and Koo, et al. 2004). One such study, which is widely referenced, was sponsored by the U.S. Federal Highway Agency (Salmon, et al., 1997, and Elias, 2001). It recommended that PET geogrids (either in the form of yarns or straps) should have a molecular weight greater than 25,000 and a carboxyl end group of less than 20. It furthermore recommended a limiting pH-value since the study indicated that degradation increased 2.4 times as the pH increased from 7 to 10.

These findings stimulated a subsequent research project (Koerner, et al. 2001 and 2002) which investigated field conditions behind a number of existing masonry block walls. Twenty-five walls across the USA were sampled and evaluated for their alkalinity as measured by pH-values. The walls varied in age from 0.5 to 8-years and were in many different soil conditions. The walls were sampled in three different zones behind the masonry block facing; drainage soil, reinforced soil, and retained soil. Figure 1(a) shows these approximate locations, and Figure 1(b) presents the resulting pH-values.

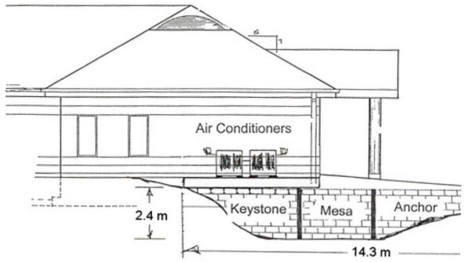


(a) Monitoring zones behind masonry block



(b) Results of field monitoring for pH- values

Figure 1. Locations and results of field monitoring of 25-walls for pH-values, Koerner, et al. (2001).



(a) Elevation view

(b) Photograph of wall

Figure 2. Sketch and photograph of masonry block wall being used for pH-monitoring purposes.

2 THE GSI WALL

The full-scale wall discussed in this paper was constructed to replace a failed timber wall which supports two air conditioners outside of the Geosynthetic Institute's (GSI) building in Folsom, Pennsylvania, USA, see Figure 2. As seen, it is a masonry block retaining wall, however, it is constructed in three sections each containing a different type of masonry block. Keystone, Mesa and Anchor are the three different block types, all of which were locally manufactured. Manufacturing was by the dry-cast method with steam curing for all of the blocks, but subtle (and largely unknown) differences undoubtedly exist. The wall has a maximum height of 2.4 m and length of 14.3 m. It is geogrid reinforced with PET yarn-type woven geogrid. The geogrid has a PVC coating, a mass per unit area (ASTM D5621) of 235 g/m^2 and an ultimate wide width tensile strength (ASTM D4595) of 35 kN/m in the machine direction and 20 kN/m in the transverse direction. The geogrids were placed at 400 mm vertical spacings, i.e., every two bock interval. The entire area behind the blocks was filled with AASHTO No. 57 stone (average size = 37 mm) from a limestone quarry. Thus, there are no discrete drainage and reinforced soil zones as shown in Figure 1(a). Since the entire backfill was limestone, this probably results in a worst-case condition from a pH-perspective. The wall was built in June, 2003.

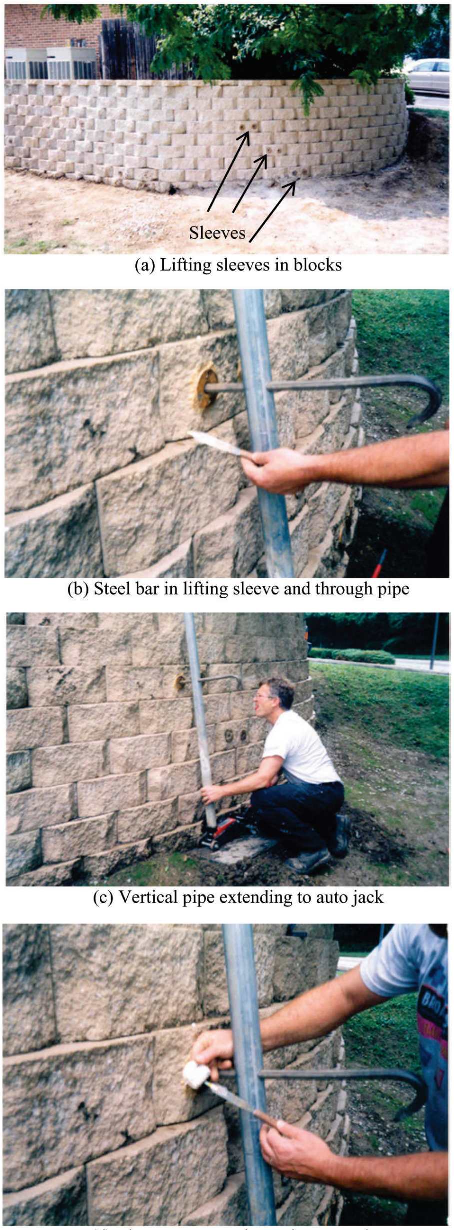
Nine blocks (three of each type) were modified to accommodate pH-monitoring. Holes were drilled through the block and metal lifting sleeves inserted. The sleeves were then epoxied in place. These sleeve-modified blocks were placed at the bottom, middle, and top, of each wall section during construction of the wall; see Figure 3(a) for a detail.

Subsequent to wall construction, pH monitoring began immediately. The process is as follows; one end of a hardened steel bar is inserted horizontally into the lifting sleeve, and the other end is inserted through a vertical pipe, see Figure 3(b). This vertical pipe extends down to an automobile jack which is at the ground surface in front of the wall, see Figure 3(c).

By mobilizing pressure in the jack, the vertical pipe lifts the horizontal steel bar which, in turn, lifts the modified block and all blocks above. One millimeter (1.0 mm) is sufficient to insert a piece of litmus paper on the end of a spatula into the space between the blocks. After a few seconds of the litmus paper becoming damp, it is removed and compared to a color change chart for determining the pH-value, see Figure 3(d). Typically, readings are taken after a heavy rain to be assured that there is moisture between the blocks. The reading accuracy is approximately one-half of a pH-unit. The entire monitoring process is very rapid. The set of nine readings can be done in 30 to 60 minutes.

3 PRELIMINARY PH-VALUES

At this point in time the wall is approximately 2-years old. Twenty-five sets of readings have been



(a) Lifting sleeves in blocks

(b) Steel bar in lifting sleeve and through pipe

(c) Vertical pipe extending to auto jack

(d) Litmus paper to determine pH-value

Figure 3. Technique of pH-monitoring between masonry blocks.

taken. Observing that there is very little difference in pH-values between the bottom, middle, and top of each block type, these three values are averaged and reported as a single value. Each block type, however, is reported separately. To date, the data is presented in Figure 4.

The pH-values are understandably the highest for the first 50-200 days after wall construction. After 200-days the trends appear to be decreasing. The Keystone blocks have the highest pH-values to date, followed by the Mesa blocks, and the Anchor blocks the lowest. That said, the differences are only 1.0 pH-units which has been relatively consistent throughout. The most recent readings have the pH-values at 8.5, 8.0 and 7.5, respectively.

It should be emphasized that to date this has not been a masonry block study. We selected three blocks based on availability and having the same face geometry. Mix design (i.e., cement content, additives, etc.), rate of curing, compressive strength, block age, percent carbonization, etc. were not investigated as of yet. The possibility of investigating such block characteristics remains as being future work.

4 COMMENTARY

Since this paper describes an ongoing-study, a firm summary and conclusions section is simply not possible. Monitoring for several more years will be necessary to establish long-term trends. However, several comments are offered so as to set targets for what may occur in the future.

First, it is of interest to observe what limiting pH-values are usually specified for geosynthetic reinforced walls and slopes. In a survey of U.S. State agencies, 27 out of 50 responded as to maximum pH-values for geosynthetic reinforcement. The maximum allowable values range between 9 and 10 which appears to be attainable by all of the block types used in this particular wall construction; all three of which are lower than this value presently. In addition, it should be noted that the manufacturers' suggest applications for such geogrids are walls, embankments and slopes with pH between 4 and 9.

Second, this study represents three block types out of perhaps fifty different types being manufactured for the North American market. In order to form a base line for possible additional enquiry, these three block types will be analyzed for unreacted cement and other parameters of interest. Whether or not a specification can eventually be made in this regard remains to be seen.

Third, the type of backfill within and immediately behind the masonry blocks is also of interest. For the wall being evaluated, we used AASHTO No. 57 stone from a local quarry which is a limestone rock quarry. Thus, any leaching of alkalinity-forming minerals is likely to be maximized. In this regard, the present study probably generates conservative results.

Fourth, an assessment of the meaning and effects (if any) of an initially high pH-value and then a long-term buffering to a near neutral value is necessary. Such studies to our knowledge have not been conducted. Furthermore, the nature and effectiveness

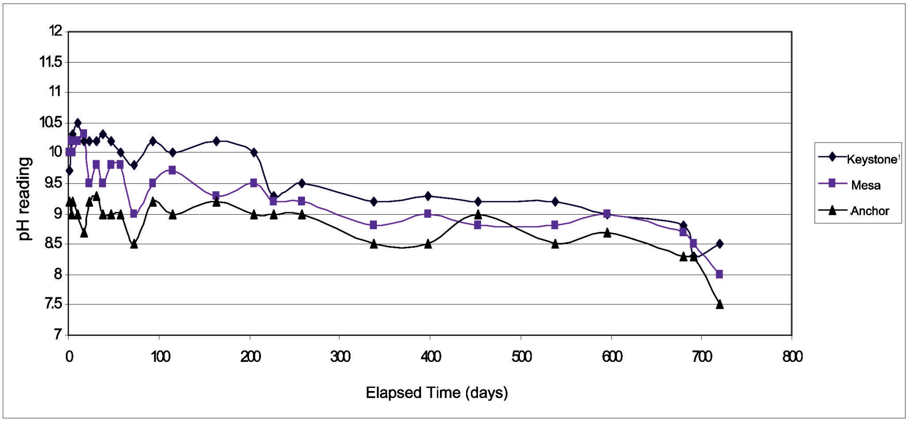


Figure 4. Two-years of monitoring data for pH-values between masonry blocks at the GSI wall.

of the PET yarn coatings (latex, bitumen or PVC) should be considered and evaluated accordingly.

Lastly, the environment of the wall is not representative of extremes insofar as precipitation (rain or snow), high temperatures, low temperatures, cyclic freeze/thaw, alternating wet/dry cycling, or saturated wall section such as in lakes or streams. Additionally, the wall is set back from the street and there is no salt spray from roads or the environment.

That said, the data represents the first of its kind and with continued monitoring will form a benchmark for further study which includes the disassembling of small sections of the wall, removing and testing swatches of the geogrid at 10, 20, and 30 year intervals for its retained strength.

ACKNOWLEDGEMENTS

The financial assistance of the member organizations of the Geosynthetic Institute is sincerely appreciated. Their identification and contact member information is available on the Institute's web site <<geosynthetic-institute.org>>.

This particular project falls under the Institute's Center for Polymeric Reinforcement of Structures (CPReS) which is a cooperative venture between GSI, Drexel University and the University of Delaware.

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