

# Relationships Between Morphological Features and Weathering Resistivity in Sandstone Layers

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## ABSTRACT

Ten layers of sandstone bedrock in western Wisconsin are examined to determine the relationships between morphological features of the rock layers and resistance to weathering. Characteristics such as bedding, joints, smoothness, weathering pits, and cementation are recorded. The saturation coefficient of each layer is calculated, which is a ratio of water absorption after 24 hours in cold water to 5 hours in boiling water. The saturation coefficient has been used in conjunction with compressive strength values as an index of the durability and freeze/thaw weathering resistivity of a material. This study indicates that some characteristics of the sandstone layers are clearly related to saturation coefficient and weathering resistivity, while others appear to be unrelated.

## INTRODUCTION

The Hixon Forest bluffs east of La Crosse, Wisconsin, are a series of rock formations that were formed millions of years ago and then weathered and eroded by a variety of geomorphic processes. Within the bluffs at Hixon Forest Park a series of sandstone layers occur that are quite different from one another (Figure 1). This study examines how some of the characteristics of a sandstone layer are related to one another, and specifically, how bedding, joints, smoothness, and weathering pits relate to the durability of a rock, which is indicated by its saturation coefficient. The sandstone layers were collected from a section of Jordan Sandstone in Hixon Forest. Jordan Sandstone is the last Cambrian-age deposit in this area (Hansen, 1970). Because all of the samples were of sandstone and from the same formation, they share many of the same characteristics. However, sandstones, even within the same formation, can have very different characteristics (International Society for Rock Mechanics, 1979). The characteristics of bedding, joints, smoothness, and weathering pits were used in differentiating the ten layers of the Jordan Sandstone. Durability is indicated by a saturation coefficient because rocks have a different numbers and sizes of pores.

The saturation coefficient compares the absorption ability of a rock after 24 hours in cold water to the absorption ability after 5 hours in boiling water. The theory is that if the pores are easily filled right away, a rock will freeze and crack. The mechanical process of freeze-



**Figure 1. Jordan sandstone outcrop in Hixon Forest.**

thaw weathering occurs when water is absorbed by a material and then freezes inside of pores or cracks. Water volume expansion causes breakage and pieces may eventually break off of the parent material completely and be eroded away (Easterbrook, 1993). This is because water increases its volume by 9% when it turns to ice and if the rock is already completely saturated the pressure of the expanding ice would have to be exerted on the walls of the rock (Latta, 1962). Boiling reveals the total amount of pore space that can be filled when pressure is exerted. A durable rock has a low saturation coefficient because the rock is able to absorb more water or handle more pressure when under adverse conditions (Gerrard, 1988).

## METHODS

Each of ten samples was collected from a different layer of the sandstone formation. Each layer was indicated by bedding planes and variations in color, texture, and weathering features. The morphological properties of smoothness, bedding, and joints for each sandstone layer were rated on a subjective scale from 1 to 10. A number 10 means that the rock had very visible bedding, was very smooth, or had a high number of joints. A second set of measured data is the size of weathering pits found within each layer. These measurements are averaged for each layer. The other major characteristic of each sandstone layer determined is the saturation coefficient of the rock.

The saturation coefficient involves absorption values and is considered an indicator of durability and freeze-thaw resistance in stone, mortar, and ceramics (Brick Institute of America, 1989). The saturation coefficient is usually evaluated in conjunction with strength compression when tests are done to determine commercial product durability. Most building materials, such as brick, must have a saturation coefficient less than .78 or .80, depending on the class of brick, in order to be used in most building projects (Brick Institute of America, 1993).

To measure the saturation coefficient of each of the sandstone layers I prepared the rock samples to keep them relatively similar. This involved removing the weathering rind on the outer surface of the rock because I assume the rind would inhibit absorption. The first step to determine the saturation coefficient is drying the sandstone samples for 24 hours at 235° Fahrenheit, letting them cool, and then weighing them. The samples are soaked in cold water for 24 hours, wiped free of excess moisture, and then weighed again. The next step is to boil the samples for 5 hours. After that time the samples are again wiped free of excess water and weighed. The saturation coefficient is calculated with the following equation:

$$\text{Saturation Coefficient} = (Wc - Wd) / (Wb - Wd)$$

Where,  $Wd$  = dry weight of the specimen,  $Wc$  = saturated weight of the specimen after 24-hr submersion in cold water,  $Wb$  = saturated weight of the specimen after 5-hr submersion in boiling water (Objective No. 5B)

## RESULTS

When the characteristics of smoothness, bedding, and joints are graphed on a column chart (Figure 2), it is shown that the three characteristics do not appear to have any relationship with each other. Some layers are quite smooth, have visible bedding, and have multiple joint and yet others less than a meter away are smooth and without clear bedding or joints. In one sample, one characteristic could be clearly visible while other characteristics were not,

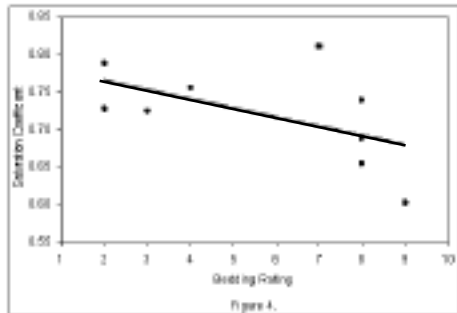
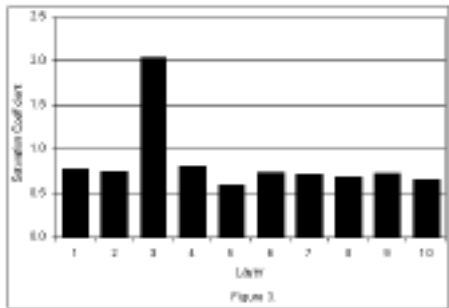
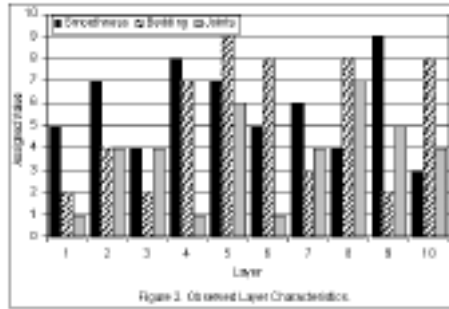
while all three characteristics could be rated high in the next layer. This may indicate that the properties measured are not related to one another. However, when each of these was compared with saturation coefficient results some relationships did appear.

The saturation coefficient results of the ten sandstone samples are shown in Figure 3. It should be noted that the clearly anomalous result for sample three is probably due to rock break-up during the boiling process, resulting in a loss of mass rather than a gain.

The following analyses are based on graphs that exclude sandstone layer three's anomalous saturation coefficient value. Gerrard (1988) comments that stones with prominent joints and bedding planes are relatively resistant to weathering and, therefore, have low saturation coefficients. The plotted data comparing visible bedding and saturation coefficient for the sandstone layers in this study show a weak negative relationship, if they reveal a relationship at all (Figure 4). Joints, on the other hand, do seem to display a somewhat stronger negative relationship with saturation coefficient (Figure 5). According to the results, sandstone layers with fewer joints are likely to have higher saturation coefficients, which agree with Gerrard (1988).

A scatter plot of weathering pit length and saturation coefficient revealed a lack of relationship between weathering pit size and saturation coefficient. On the other hand, smoother layers have higher saturation coefficients and so are less durable. The scatter plot for smoothness, however, does not reveal a very strong positive relationship and more sample tests should be done before any concrete conclusions are made.

The final relationship to discuss is that between saturation coefficient and the degree of cementation of the sand grains. Cementation was not directly measured or given a value during this study, but it was observed and noted. Observations of cementation seemed to be closely related to the durability results. One observation made was that layer four was the weakest rock and disintegrated rather easily. This was also the layer with the highest sat-

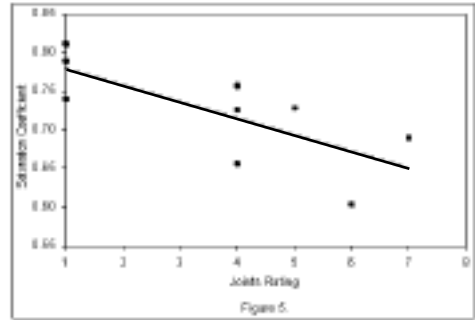


uration coefficient as shown in figure 3 (when the anomalous layer three value of 2 is disregarded). Unfortunately, no quantitative data was gathered for cementation properties of the rock layers.

## CONCLUSIONS

Based on the graphs comparing saturation coefficients to the morphological properties of bedding, joints and smoothness in this study, it is found that only joints and smoothness have a relationship

to saturation. According to the results, sandstone layers with more joints have lower saturation coefficients while smoother rocks have higher saturation coefficients. Cementation of the sandstone particles also appeared to have a relationship to saturation coefficient although this relationship was not studied numerically. Future studies should examine this particular relationship more in depth. If one were to search deeper, relationships may eventually be found which link resistance to weathering, cementation, weathering pits, bedding, and joints to a primary variable, such as rock formation processes.



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