Why Percent Open Area?

Percent Open Area - Its History, Role, Function, and Importance in the Mechanics of Geotextile Filtration

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Introduction

Contrary to popular belief, fabric Apparent Opening Size (AOS/EOS), permeability, permittivity, and flow rates have no relationship to the "clogging resistance" of a geotextile in filtration/drainage and erosion control systems. However, a direct relationship does exist with Percent Open Area, but few design engineers today seem to understand why it's so important or, even more importantly, how it contributes to the success of a fabric/soil filtration system. The following is a compilation of previous research on what has become a rather sensitive issue in the geotextile industry.

History

In the past, one of the most important criteria to consider when designing fabric/soil filtration systems was Percent Open Area which promoted the initial passage of fines through the fabric (U.S. Army Corps of Engineers, 1972). This contradicts today's conventional design criteria for retention which ensures that soil particles do not pass through the geotextile. Percent Open Area was the key to this early design methodology and is essentially unique to certain types of woven monofilament fabrics. This uniqueness caused manufacturers of other types of products to launch a campaign to establish uniform clogging criteria for all types of fabrics.

Since Percent Open Area cannot be measured in nonwoven geotextiles, a fabric/soil test using site-specific soils was required for them instead. In the "real world" this rarely, if ever, takes place. Porosity, the ratio of void volume to total volume, was later offered as a substitute measurement for nonwovens as an equivalent to Percent Open Area in wovens. Porosity is rarely measured directly and is instead *"calculated"* from other properties of the fabric, as opposed to Percent Open Area which is determined by direct *"measurement"*. Also, Porosity does not take into account any load being placed on the fabric or the fact that the openings are not distinct or uniform through the thickness of the fabric.

Eventually, as a result of continuing efforts to establish uniform clogging criteria for all fabrics, Percent Open Area, along with its relative importance to filtration/drainage and erosion control applications, became only vaguely familiar, if at all, to many design engineers. Values for Percent Open Area are seldom seen in tables or *Buyers Guides* which are published by various periodicals; even the term Percent Open Area has disappeared from many Glossaries of Geosynthetic Terms.

Mechanics of Filtration

Basically, *clogging* of a geotextile is caused by the retention of particles inside the fabric, while *blinding* is caused by the blocking of individual openings on the upstream side of the fabric. A simple solution to these critical problems is to select a filter fabric with uniform openings small enough *(AOS/EOS)* to retain the sand/soil particles, yet large and frequent enough *(Percent Open Area)* to allow any fines in suspension to pass through the fabric. This results in the formation of a bridge network or *mini-graded filter* in the soil immediately adjacent to the fabric and provides the majority of future filtration and retention (See Figure 1). Once this has been established, piping (loss of fines) ceases and the system is considered to be in equilibrium. The filter fabric is now actually contributing to the permeability of the fabric/soil filtration system while retaining the mini-graded filter in place and preventing it from collapsing into the drainage layer. If the initial release of fines through the fabric had not taken place, then *clogging* of the *fabric* and/or the *soil* immediately adjacent to the fabric could have occurred.

Why Percent Open Area?

Percent Open Area is the area of distinct, uniform, and *"measurable"* openings of a geotextile that is not occupied by filaments or yarns. This property can assure the design engineer that a certain *"frequency"* of these openings exists in a given area of the geotextile. This is not to be confused with AOS/EOS which relates to an opening's size or *"retention"* capabilities - not "frequency". For example, it's quite possible to have an AOS/EOS of 70 - but have only 3 openings in a given square inch of a fabric if Percent Open Area is not specified. On the other hand, permeability, permittivity, and flow rate are representative of a fabric's *"hydraulic"* properties. Unfortunately, too many specifications are written today that rely on the "retention" and "hydraulic" properties of a fabric as a safeguard against clogging. Although each plays an important role in the success of the soil/fabric filtration system, neither contributes to the clogging resistance of the geotextile. If the geotextile fails, the entire soil/fabric system fails.

When using the published hydraulic values of a geotextile in the design of filtration/drainage and erosion control systems, it's important to realize that these values were attained under controlled laboratory conditions and without soils. Some of the fabrics with the highest hydraulic values in the lab have been among the first to clog when used in conjunction with soils. Therefore, the overriding concern of the design engineer should be the required permeability values of the soil/fabric filtration system in the field, after migration has ceased and permeability has stabilized.

A unique *"behavioral"* characteristic of Percent Open Area is that water and soil particles travel in a *"unidirectional"* (direct) path to both enter and exit the fabric - quickly and without interference. In a nonwoven fabric (See Figure 2), the path that fines take in their migration through the geotextile is longer and more tortuous - *"multidirectional"* (indirect). Fine silt and soil particles at the interface of a nonwoven fabric are conveyed into the fabric matrix by water movement. These particles can then move within the plane of the fabric eventually becoming locked *within* the fabric matrix. They tend to form a consolidated wall. To some extent, this phenomenon is even encountered with glass beads when determining AOS/EOS.

Another reason for this behavior in nonwovens is their lack of *uniform* openings through the thickness of the fabric (See Figure 2). For example, although the results of AOS/EOS testing might obtain values of 70-100 for the geotextile, the openings at the surface of the fabric could very well be 30-50, further promoting the intrusion of particles into the fabric. It should be noted that AOS/EOS values are also determined without any load on the fabric. It is well known that, under compression in the field, the thickness of nonwoven fabrics is reduced considerably, with subsequent changes in pore size and porosity, which in turn affects the performance of the fabric. Even though virtually all available nonwoven geotextiles vastly exceed current porosity criteria, Porosity values offer no resistance to clogging of the fabric. In fact, there are no physical properties that can be attributed to nonwoven geotextiles that can assure the design engineer that these events will not occur as described - it's inherent to the construction of the fabric.

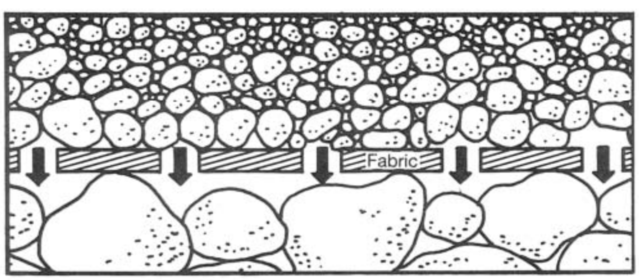

Figure 1: Formation of Soil/Fabric Filtration System Using a Woven Monofilament Fabric

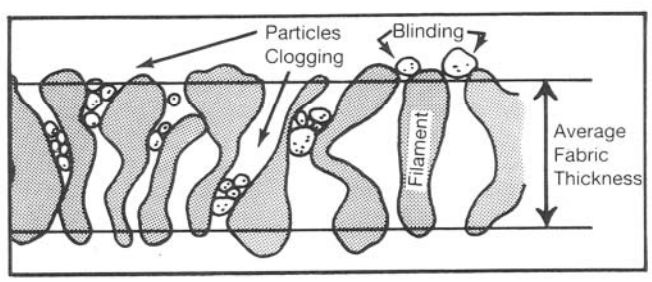

Figure 2: Methods of Clogging and Blinding in a Nonwoven Fabric

Summary and Conclusions

It's important to note again that AOS/EOS relates to *opening size* and *retention*, not *frequency*. This property is determined using glass beads that are round and were designed to pass through the fabric. On the other hand, silt particles are usually angular, and, in the field, bridging occurs between these particles enabling a geotextile to often retain soils many times smaller than the opening size of the fabric. Data from the Gradient Ratio tests conducted by Haliburton confirmed that, even though AOS/EOS values for the six tested fabrics varied from 40 to 70, all fabrics satisfied both the original 1972 Calhoun and 1977 Corps of Engineers piping criteria. Also, the issue has been raised, on occasion, as to whether or not geotextiles with high percent open areas might allow an excessive loss of fines through the fabric. This argument completely disregards the eventual formation of the mini-graded filter. Futhermore, *retention* has never been a function of Percent Open Area. That distinction belongs to AOS/EOS and should always be specified together with Percent Open Area.

It is Percent Open Area's unique combination of (a) distinct, measurable, and uniform openings, (b) frequency of openings, and (c) unidirectional transmission paths that ensures avenues of escape for fine silt and soil particles. This is critical to the formation of the mini-graded filter, and has been documented as the best possible deterrent to clogging and/or blinding of the geotextile and possible failure of the project.

In essence, these two types of geotextile fabrics, woven monofilaments and nonwovens, *function differently* in their mechanism of water/particle transmission, and the key differentiating property between the two is Percent Open Area. Without fabric/soil filtration tests using site-specific soil, Percent Open Area remains the single most important property to consider when hydraulic gradients are medium to high, long-term filtration is critical, internal migration of fines may occur, and/or even partial clogging of the fabric could result in failure of the project.

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