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The Dual Roles for Using MARV

by

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Abstract

As it has transpired over the 30± years since the minimum average roll value (or MARV) concept's origin, dual roles have targeted entirely different segments of the geosynthetic industry. One role is focused toward manufacturers and specifiers, the other role is for field acceptance of roll shipments for a specific project.

Regarding manufacturers and specifiers, the concept is to have a product's minimum properties within the mean minus two standard deviations, or $\overline{X} - 2S$. Similarly, the concept is $\overline{X} + 2S$ if the focus is on the maximum properties and is then called the maximum average roll value (or MaxARV). *Regarding field acceptance* of an entire "lot" of geosynthetics for a specific project, however, the concept is to select a very few number of rolls for testing which hopefully results in confidence that the entire shipment is acceptable.

The MARV concept was originated to address the relatively high test property variation of lightweight nonwoven geotextiles. As such, the concept is felt to be very appropriate for geotextiles. However, over the years it has spread to many other geosynthetic materials. In this regard, the annual Specifiers Guide of Geosynthetic Magazine requests that manufacturers submit MARV or MaxARV values ($\overline{X} \pm 2S$) for the majority of the index test values of their listed products with the exception of geomembranes and erosion control products. Its use is certainly appropriate for geotextiles but not necessarily so for other geosynthetics. The closely related role for the use of MARV (or MaxARV) is in the field for acceptance of job lots. The procedure makes use of a limited number of rolls and is again best suited for geotextiles but can also be used for acceptance of other geosynthetics at the discretion of the design

engineer. The concept behind MARV and both roles of using MARV are described in this White Paper.

The Dual Roles for Using MARV

This White Paper is meant to not only explain the dual roles of MARV to manufacturers/specifiers and field acceptance personnel, but also to explain the concept and its statistical background.

1.0 Background of MARV vis-à-vis Minimum Average

While there have been several articles explaining the concept of minimum average roll value (MARV) of geotextiles, e.g., Narejo, Hardin and Ramsey in the September 2001 issue of GFR and Koerner (2005), the topic continues to be less than universally understood and the cause of several serious disputes. While manufacturers use of MARV is quite clear, there are nonagreed upon ways in which geotextile conformance acceptance is practiced. This leads to confusion for the parties involved particularly in the field; including the owner, regulator, designer, manufacturer/ distributor, inspector and contractor. This White Paper explains what is felt to be the agreed upon practice involved in the dual roles of MARV with respect to (i) manufacturers reporting of geotextile property values, and (ii) the generally accepted methodology for field CQA testing acceptance.

The minimum average roll value (MARV) concept was jointly developed by geotextile users and manufacturers while crafting acceptance protocols in the early 1980's. The concept was actually a negotiated middle-ground between the user (often a civil engineer) accustomed to requiring absolute minimum values and the textile manufacturers accustomed to providing average values in their product listing of numeric test values. Since the difference between absolute minimum and average can be large within lightweight nonwoven fabrics, a compromise was necessitated. It must be emphasized that the original MARV concept applied only to geotextiles. No other geosynthetic materials; geomembranes, geosynthetic clay liners (except for their geotextile components) geonets, geocomposites (except for their geotextile components), geogrids, geofoam, geopipe, etc. were included in the original discussions.

On occasion, a maximum value is specified and this becomes a MaxARV value, e.g. as with apparent opening size for geotextiles. That said, we will only refer to MARV herein since it is appropriate for the vast majority of properties which are invariably focused on minimum values.

Manufacturers of all types of geosynthetics evaluate average roll values of many test properties on an ongoing basis. It is these values, tempered by statistical variations, which are published in their literature and on their websites. For example, if they publish the mean (average) value minus two standard deviations ($\bar{X} - 2S$) of a particular test property they are indeed following the MARV protocol. In today's specification listings this is the case with geotextiles. Other geosynthetic manufacturers, and particularly geomembrane manufacturers, publish minimum average values, or $\bar{X}$.

In quite a different role, a *field inspector* tasked with evaluating a shipment of rolls of geosynthetics for a specific project is confronted with a very challenging question, i.e., should he/she accept the shipment or not? This is the second issue to which MARV is addressed. To be sure, a field inspector is at liberty to test and evaluate as many, even all, of the rolls sent to a specific job site. On the other hand, the MARV protocol addresses selected rolls of the entire shipment sent to the job site. This entire shipment is generally referred to as the "lot" of rolls for that particular job. The hierarchy of terminology (from largest to smallest) is as follows:

- lot = the collective group of rolls for the entire project
- roll = any individual roll within the lot
- sample = a cut portion (often the roll width by 3 ft [1.0 m] of length) of any roll sent to a laboratory for testing
- coupon = a portion of the sample sometimes used for conditioning as with incubation in a weathering device
- specimen = the precise size and shape which is die cut from a sample or coupon for laboratory testing per the relevant test method

The MARV protocol per ASTM D4354 calls for determining the number of rolls in the entire lot and taking a limited sampling within it. See Table 1 for such guidance.

Table 1 – Number of Rolls to be Selected as the Lot Sample for Purchaser's Field Specification Conformance (ASTM D4354)

Number of Rolls in the Lot	Number of Rolls Selected for Testing*
1 to 2	1
3 to 8	2
9 to 27	3
28 to 64	4
65 to 125	5
126 to 216	6
217 to 343	7
344 to 512	8
513 to 729	9
750 to 1000	10
1001 or more	11

*The number is actually the cube root of the upper range of the rolls in the lot.

Thus, for a project consisting of 126 to 216 rolls (i.e., the lot) six rolls should be randomly selected for sampling and subsequent laboratory testing. If the minimum average of these six meets the specification, the entire lot of 126 to 216 rolls is accepted. If not, six different rolls are tested and if they meet the specification the entire lot is accepted. However, if this second set of samples also fails, the entire lot of 126 to 216 rolls is rejected. The above discussion embodies the MARV process vis-à-vis field conformance acceptance of geotextiles.

2.0 Obtaining the Minimum Average Roll Value (MARV)

Depending upon the particular geotextile being manufactured there is invariably some amount of property variation. Additionally, the equipment and procedures used in testing of these products introduces some degree of variability. Together, these items result in a statistical variation of physical, mechanical, hydraulic and endurance test values of any given product. Even when a number of replicate samples are tested and averaged together there is a spread in the results. This spread is statistically addressed using the average (or mean) value of a particular property and its standard deviation.

Average (or Mean) Value

Figure 1 following shows a normal distribution of a data set which is generated when many test results are measured on a specific test property value. This applies to properties such as mass/unit area, tensile strength, puncture, tear, etc. By the law of large numbers, the curve is usually symmetrical (statistically, it is called a Gaussian distribution or even an “bell-shaped” curve) and the most frequently measured value is defined as the average (or mean) value. Prior to 1980±, this was the usually reported value by many geotextile manufacturers.

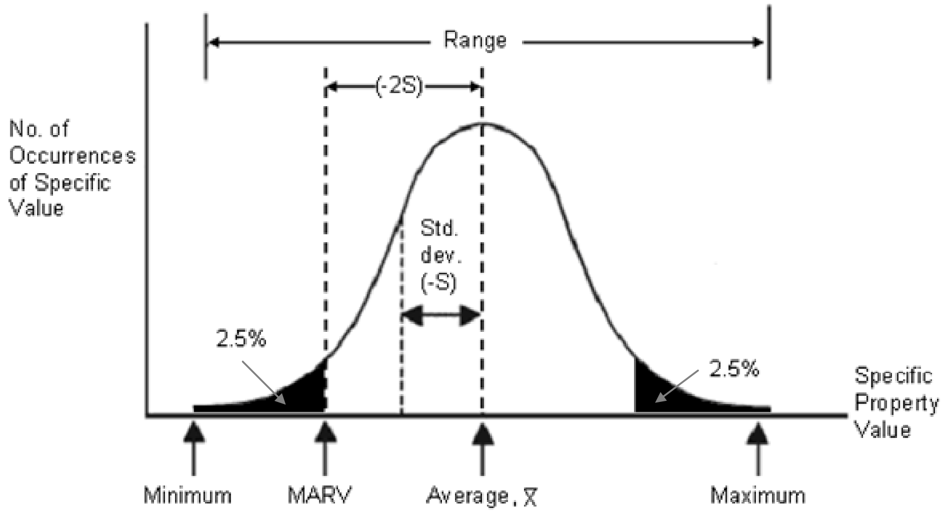

Figure 1 – Graphical Interpretation of Various Qualifying Values, i.e., Minimum, MARV, Average, Maximum, and Range

Standard Deviation

One measure of the variation involved in the product's manufacturing and testing processes is the standard deviation of the test values in question. Statistically, standard deviation(s) is defined as follows:

> "The square root of the arithmetic mean of the squares of the deviation of each of the class frequencies from the arithmetic mean of the frequency distribution."

Mathematically, the two parameters of average (or mean) and standard deviation are defined by the following two equations:

$$\overline{X} = \Sigma X_i / N \tag{1}$$

$$S = \left[\frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \ldots + (X_N - \overline{X})^2}{N - 1} \right]^{1/2} \tag{2}$$

where

$\overline{X}$ = average (or mean) value,

X_i = any measured value, and

N = number of measurements

S = standard deviation (from the average, or mean)

The significance of standard deviation lies in the variation in material properties and testing procedures of the particular property under investigation. For a normally distributed curve, plus and minus one standard deviation ($\overline{X} \pm S$) from the average will include approximately 67% of all measured values. This is indicated on Figure 1. Plus and minus two standard deviations ($\overline{X} \pm 2S$) includes approximately 95% of all measured values and it is also indicated. Additionally, indicated on Figure 1 are the absolute minimum and maximum values (close to $\overline{X} \pm 3S$), which in the past have been the specified values used by many regulatory agencies and engineering specifiers.

<u>Minimum Average Roll Value (MARV)</u>

After many discussions in the early 1980's over a mutually acceptable value to be reported in product specifications of geotextiles (varying from absolute minimum-to-average) the average minus two standard deviations was agreed upon. Thus, it is generally agreed upon (at least in North America) that manufacturers should report geotextile product values of $\overline{X}$ - 2S and regulators and designers should specify values in an identical manner. *This is defined as "MARV"*. Note, that when maximum values are required the concept shifts from *MARV to MaxARV and is calculated on the basis of* $\overline{X}$ *+ 2S.* MARV represents 97.5% of the possible measured values since all values in excess of MARV are acceptable. Likewise, when MaxARV is involved again 97.5% of the values are included since the "tail" of the curve in both cases exceeds the relevant value.

3.0 MARV's Role for Geotextile Manufacturers and Specifiers

Having test property data for thousands of rolls of a particular product, a geotextile manufacturer should have no problem with obtaining reliable statistics of mean and standard deviation for the various test properties that are being measured. The total number of like rolls being produced could certainly be called a lot, but is also called a "campaign" due to the ongoing production of like product over days, weeks, months, or years. These values of MARV, i.e., the $\overline{X}$ - $2S$ values of all properties being measured, is what should appear on the manufacturers websites and product literature. To our knowledge it is regularly done for geotextiles but never done for geomembranes. Other geosynthetics are sometimes MARV related and sometimes "minimum average", or even "average" related. The point is that a geotextile manufacturer with a relatively large statistical variation in product test values can and should give $\overline{X}$ - $2S$ values thereby referencing it as MARV. Other geosynthetic materials, particularly geomembranes, have much "tighter" statistical variations and the necessity of a MARV procedure is not as necessary and is left to the individuals involved. In this regard it can be considered as being an ongoing discussion.

4.0 MARV's Role for Field Inspectors Acceptance

Once MARV (at $\overline{X} - 2S$) is established by the manufacturer and specified accordingly, the issue of field conformance of the supplied rolls of the intended product to the specification value must be addressed. In general, a field inspector has neither the time nor the resources to test every roll of the project lot and, as such, needs a "shortcut" procedure. The following example based on a limited MARV value illustrates this process.

Assume that samples from a representative number of rolls are removed from the entire shipment to the job site (i.e., the lot) and sent to a laboratory for testing; recall Table 1 for the required number of rolls. Specimens are then taken from these samples according to the appropriate test method. The measured values of these specimens are averaged for each roll. As shown in the example of Table 2; six rolls were evaluated with ten specimens tested on each roll. The specimen values are then averaged and by observation the lowest average test value for any roll is seen to be a numerical value of 623. This defines MARV for this set of limited rolls within the entire lot.

Table 2 – Example of MARV Obtained for Six Roll Samples

Test Number	Roll Number					
	1	2	3	4	5	6
1	643	627	637	642	652	637
2	627	615	643	646	641	624
3	652	621	628	658	639	631
4	629	616	662	641	657	620
5	632	619	646	635	642	618
6	641	621	633	642	651	633
7	662	622	619	658	641	641
8	635	628	636	662	645	625
9	641	631	627	627	651	635
10	659	625	642	660	647	641
Average =	642	623	637	647	647	631

On this specific project, the lowest average test value (the 623) must meet or exceed the regulatory, designer’s, or manufacturer’s specified MARV value for the product. In that case, the complete shipment or lot, is acceptable. Note that there are several test specimen values lower than 623 in Table 2. They represent the 2.5% of the normal distribution shown in Figure 1 to the left of the MARV value.

If any of the minimum roll values in Table 2 do not meet the specified value then resampling of a new set of six rolls from the lot is allowed. If then, this second set of six rolls meets the specified value the entire lot shipment of 126 to 216 rolls are accepted. If, however, this second sequence of tests has one or more average roll values which do not meet the specified value, the entire lot shipment of 126 to 216 rolls is rejected. This is the role of the MARV concept with respect to field conformance and acceptance procedures.

5.0 Recommendations

For the first mentioned role for MARV, geotextile project specifications should definitely use MARV, it being statistically equal to $\overline{X}$ - 2S. The exception being for apparent opening size (where MaxARV becomes necessary it being $\overline{X}$ + 2S) and for UV exposure (where the establishment of MARV would require excessive testing of this long-term endurance type of test). For regulatory purposes and for design engineers, the use of MARV or MaxARV in geotextile specifications will result in unequivocal communication with manufacturers, resulting in a lower number of rejected rolls and a more economical product.

The second mentioned role for MARV, namely the product field conformance to a specification, MARV or MaxARV takes on a different role than for manufacturers in that a select few rolls from the "lot" are sampled, tested, and assessed accordingly. Admittedly, the selection procedure is somewhat subjective (e.g., the cube root of the lot, the protocol if the first or second set of samples fails, etc.) but it is reasonable for geotextiles which can have rather large statistical variations. This procedure is not recommended for geomembranes since properties such as thickness, asperity height, etc. should be tested for every roll. Other geosynthetics such as geogrids, geonets, composites, GCLs, etc., must be tested per the project-specific plans and specifications.

It is clearly the design engineer's role to make the field conformance decision on whether to use a MARV procedure or not on a project-specific basis.

6.0 References

AASHTO M288-06 Standard Specification for Geotextile Specification for Highway Applications, Appendix "A", Washington, DC, 12 pgs.

ASTM D4354, Standard Practice for Sampling of Geosynthetics for Testing, ASTM, West Conshohocken, PA.

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