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A reassessment of HDPE geomembrane seam specifications

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ABSTRACT: Initially HDPE geomembrane seams were assessed by measurements of shear strength and the observation of the location of failure in a peel test. Then a measurement of peel strength was added, followed by measurements of shear elongation and peel separation. In this paper it is shown that measurements of shear and peel strengths do not provide meaningful data. Only peel separation and elongation provide information that can usefully be used in QC/QA tests to assess the bond efficiency and potential durability of the seam.

1. INTRODUCTION

The only reason for making a seam in a geomembrane is to make it leak tight to the contents of the lining system. However, the seam must not only be leak tight at the time of installation and during quality assurance testing, it must remain leak tight under service stresses for the expected lifetime of the lining system. Therefore, although a geomembrane is theoretically required only to be a barrier to fluid flow, and not a load bearing structural member of the lining system, seams must be such that they will transfer any tensile forces from sheet to sheet without shearing, and they must be required to resist peeling.

It is often stated that peeling forces do not occur in the field. This is not correct as clearly shown in Figure 1. Peeling forces can occur at the edges of wrinkles, which often align themselves along the more rigid seam. They occur when a geomembrane is dragged on a soil subgrade or when soil is spread on top of a geomembrane in a direction against the seam overlap. As demonstrated by Giroud(1984), they also occur when a seam is subject to shear stresses as the seam attempts to rotate to align the two joined sheets. However, a peel test is performed on a seam specimen not to reproduce field conditions, but simply to assess the quality of the seam bond.

Geomembrane seams are conventionally evaluated by testing 5 specimens in shear, (applying tension across the seam) and 5 specimens in peel, (tensioning the upper sheet and the flap of the bottom sheet in a 180 degree peeling action). Typically the shear strength is measured and required to exceed approximately 90% of a specified geomembrane yield strength (Peggs & Rollin, 1994). It may be required that the specimen break "outside" the seam in what is termed Film Tearing Bond (NSF, 1993). Similarly it is typically required that peel specimens fail in FTB, often without even measuring a peel strength. The definition of FTB is unclear. To most it probably means "failure in the geomembrane".

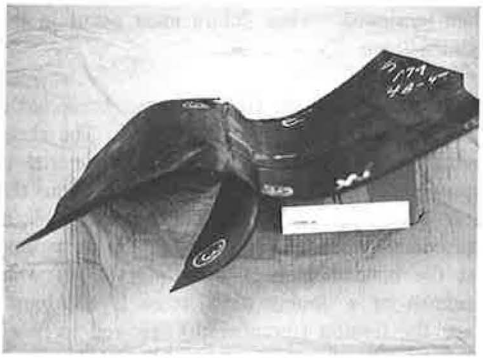

Figure 1. Peeling force on seam as geomembrane pulled to the right (Peggs et al. 1994a).

In 1987 Peggs demonstrated the need to assess the ductility of the shear specimens, since if the specimen fails outside the seam (in FTB), but in a brittle manner, the durability of the adjacent geomembrane has been compromised during the welding process, either by excessive grinding, or more usually by overheating. Overheating increases the susceptibility of the geomembrane adjacent to the seam to stress cracking by consuming protective antioxidants, increasing oxidation and increasing crystallinity. Overheating can also cause stress concentrating notch geometries on the bottom of the geomembrane. FTB is therefore not an adequate criterion. The geomembrane must also be ductile. The term FTB should be stricken from the geosynthetics dictionary.

Peggs (1987) also showed that when an HDPE geomembrane seam is not adequately bonded and separates in a peel test, crazes that are the precursors of stress cracks may be induced in the separated surfaces. The mechanical durability (stress cracking resistance) of a seam with crazes can be reduced by a factor of 70% (Peggs et al., 1990). Since peel stresses do occur in the field, seams that separate in the peel test should not be allowed to remain in service. Nevertheless, FTB has often been interpreted to allow any amount of peel separation provided the seam does not completely separate, and provided failure finally occurs through the geomembrane. So how much peel separation is acceptable - 95%, 90%, or 50%, or only 5%? Why not zero? It can be done.

Let us reassess the various seam parameters.

1.1. *Shear strength*

It is necessary that the seam does not come apart when tensioned. Thus failure must occur in the geomembrane.

Let us assume that the HDPE geomembrane has a yield strength of 14 MPa (2000 psi). The shear strength of a homogeneous isotropic material is approximately 50% of the yield strength. Thus the shear strength of the geomembrane is approximately 7 MPa (1000 psi). Let us assume that the bonded area of a 25 mm (1 in) wide specimen of a double track seam is 650 mm^2. Thus, the tension (force/width) required to shear that area, assuming it is well bonded and equivalent to homogeneous material, is 175 kN/m (1000 ppi). No HDPE geomembrane is capable of withstanding that tension. A 2.5 mm (100 mil) thick geomembrane seam specimen 25 mm (1 in) wide, with a yield strength of 14 MPa (2000 psi), will break at a tension of 35 kN/m (200 ppi), only 20% of the targeted shear strength of the seam. A 1 mm (40 mil) thick geomembrane seam specimen will fail at 14 kPa (80 ppi), only 8% of the optimum shear strength of the seam. Thus, if the bond efficiency of a 1 mm thick geomembrane seam were 10% (over 8%), and that of a 2.5 mm thick geomembrane seam were 22% (over 20%), failure of the shear specimen would still occur in the geomembrane. Thus the measurement of shear strength does not adequately assess the bond strength of the seam unless it is excessively bad, in which case the specimen will likely fall apart during handling before it can be placed in the grips of the tensile machine.

1.2. *Shear Elongation*

If the seam has been excessively ground in preparation for extrusion seaming, or if it has been scratched by the seaming machine, the geomembrane will fail with a low strength value and a low elongation value. If the geomembrane has been overheated, resulting in an increase in crystallinity and density , the break strength will be high but the break elongation will be low. Both these conditions are damaging to the mechanical durability of the geomembrane and should be avoided. Only a low elongation identifies both these conditions and is, therefore, the most meaningful parameter to measure in the shear test. It is a far more useful indicator of seam quality than is shear strength, which as shown above can be effectively ignored. Shear elongation should exceed 100% of the distance between the edge of the seam and the nearer grip of the sheet in which failure occurs.

1.3 *Peel Strength*

When a seam is made, the bond strength between two surfaces should be independent of thickness, yet according to National Sanitation Foundation International Standard 54, a 1 mm (40 mil) thick geomembrane seam is considered acceptable if its peel strength is 230 N (52 lb), while that of a 2.5 mm (100 mil) thick geomembrane seam is required to be more than 580 N (130 lb). Thus, the thicker geomembrane is far more critically assessed than the thinner geomembrane, even though the parameter being assessed is the same. The same problem occurs as in the shear test - the strength of the geomembrane is insufficient to allow the seam bond strength to be effectively measured.

Performing a peel test is basically identical to performing a tear resistance test (ASTM D1004(c)) on a 25 mm (1 in.) thick geomembrane if the seam is assumed to be effectively homogeneous material, as is the objective of seaming. The acceptable NSF 54 tear strength for an HDPE geomembrane 2.5 mm (100 mil) thick is 290 N (65 lb). Therefore the equivalent strength of an homogeneous seam 25 mm (1 in) wide should be 2.9 kN (650lb). However, once again the geomembrane will fail at forces of approximately 0.58 kN (130 lb) and 0.23 (52 lb) for 2.5 mm and 1.00 mm thick specimens respectively. Thus the bond strength will not be challenged at efficiencies higher than 20%. Therefore, peel strength is meaningless in providing information on a realistic level of bonding between the two geomembranes. It only assess the quality of the geomembrane adjacent to the seam, providing much the same information as in the shear test. It is, however, recognized that bending in the peel test produces a more challenging stress field than in the shear test but the general principal outlined above is still applicable.

1.4 *Peel Separation*

As indicated above, in the peel test only a very poor seam, with a bond efficiency of less than 20%, will separate. Thus it should not be difficult to make a seam that will not separate at all. Practical field experience confirms this. As long as the geomembranes are used to apply the peel force to the seam interface it will not be possible to adequately evaluate seam bond strength. Only by measuring the force required to separate a seam using a driven wedge (Peggs 1987) or some other tool will measurements of realistic bond strength be possible. Such tests are difficult and impractical to perform on a QC/CQA basis.

As a result of this analysis, it is evident that the only destructive test that is required to effectively assess HDPE geomembrane seams is the peel test, since it will provide information on both the minimum required criterion for bond strength (no separation) and the effects of welding on the adjacent geomembrane (no loss of ductility). Five specimens should be tested, and all five should be required to meet specifications.

The specifications for elongation in a peel test can be the same as those previously recommended for shear tests; a minimum of 100% of the distance between the edge of the seam and the adjacent grip between which break occurs. A specimen that has adequate ductility in the peel test will certainly have no major surface and internal flaws or microstructural anomalies.

2. CONCLUSION

An analysis of peel and shear testing of HDPE geomembrane seams indicates that measurements of shear and peel strength parameters do not provide useful information on seam bond efficiencies. The only two parameters that provide useful information on the degree of bonding, and on the probable durability of the seam, are peel separation and adjacent geomembrane ductility. Both of these parameters can be evaluated in a peel test.

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