GRI-GM19a Specification

Seam Strength & Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes

- specification compliments GM13, GM17 and GM18 for geomembrane sheet
- addresses HDPE, LLDPE and fPP seams
- accommodates smooth, textured and reinforced GMs
- addresses shear and peel testing
- both hot wedge and extrusion fillet
- also, hot air and ultrasonic bonding
- discusses seam sampling intervals

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Preliminary Comments

- utilizes ASTM D6392 (both ASTM D4437 and D4545 are depreciated)
- includes shear and peel strengths
- includes shear elongation and peel separation
- gives unacceptable locus-of-break patterns (codes)

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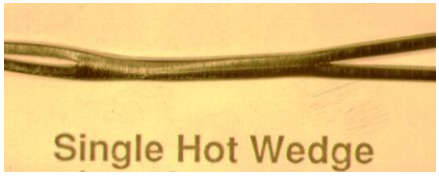
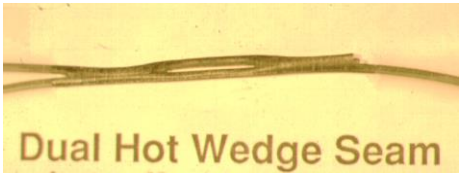
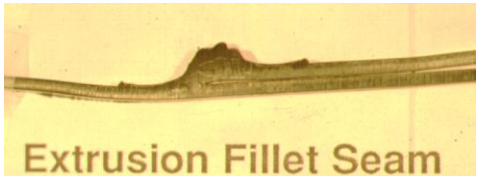
Seam Cross Section







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Field Sampling of GM Seams

- no formalized procedure or standard
- EPA technical guidance manual is available EPA 600/R-93/182 (September, 1993) by Koerner & Daniel… its dated!
- typical standard of 1 sample per 150 m (500 ft.) is suggested
- interval is based on “old” technology (solvent and extrusion flat methods)
- interval should be flexible depending on the quality of installation

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Method of Attributes

- follows GRI-GM14 Standard
- rewards “good” installers (with longer sampling intervals)
- penalizes “poor” installers (with closer sampling intervals)
- needs original and ongoing statistics
- alternative method uses control charts; but method is not standardized
- also see Control Chart Method per GRI-GM20

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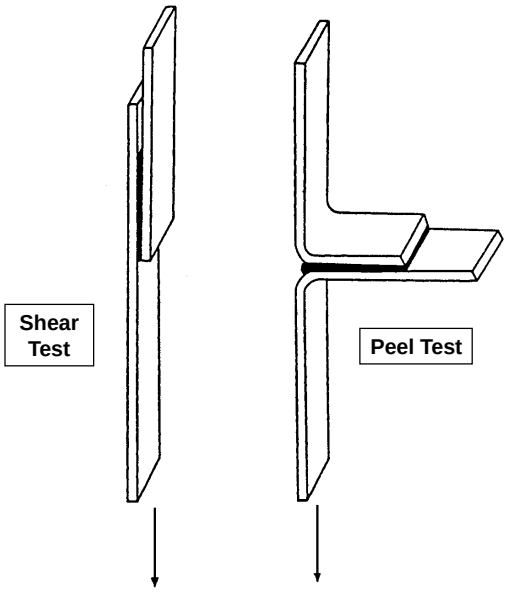
ASTM D6392

- test specimens are 25 mm (1.0 in.) wide
- specimen length $\geq$ 150 mm (6.0 in.)
- seam is located centrally and perpendicular to length
- must be cut using sharp dies
- no knives or cutting tables permitted
- two types of tests: shear and peel with 5 specimens of each type

6

D 6392



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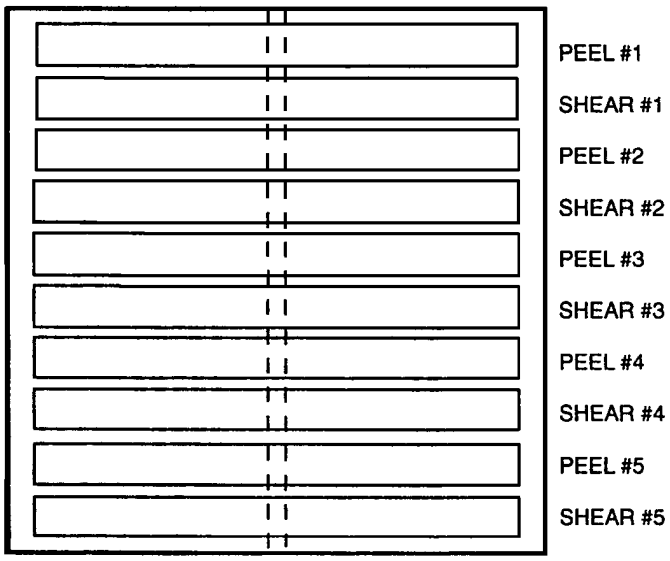
Specimen Sampling Pattern per ASTM D6392



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Regarding Shear Testing

- 4/5 must ≥ spec table value
- outlier ≥ 80% spec table value
- table values are percentages of sheet tensile strengths
- HDPE (~ 95%); LLDPE (varies); fPP (~ 75%)
- shear test follows

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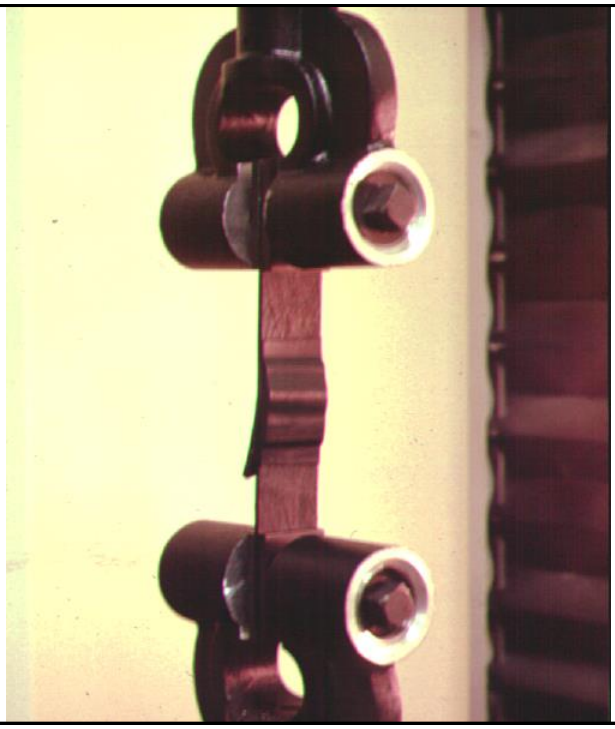
Shear Test Photo 1



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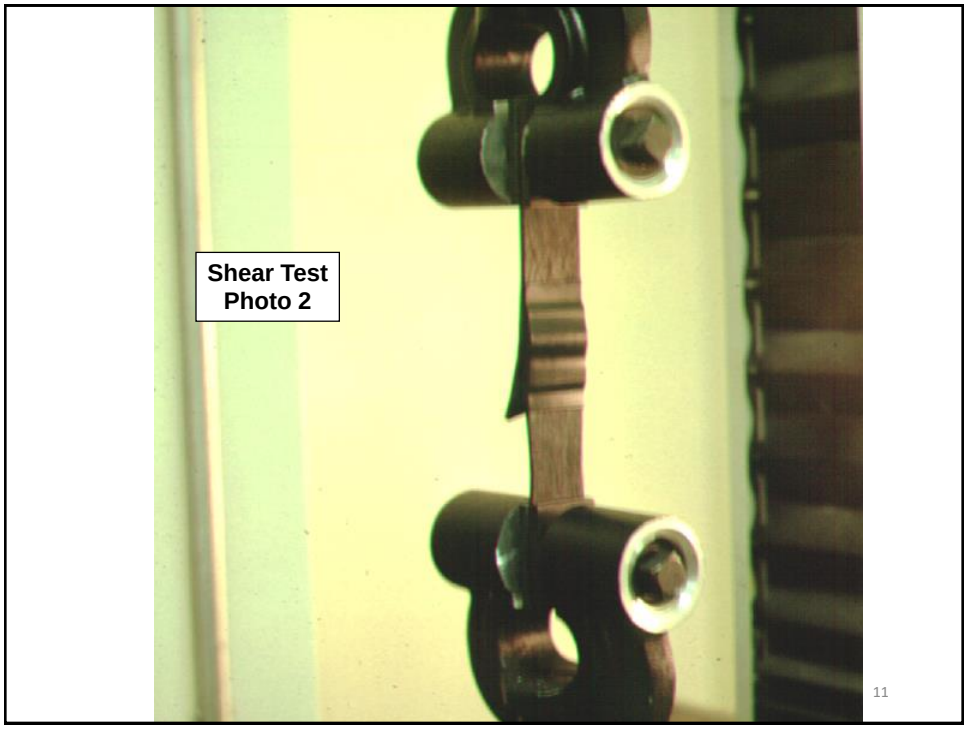
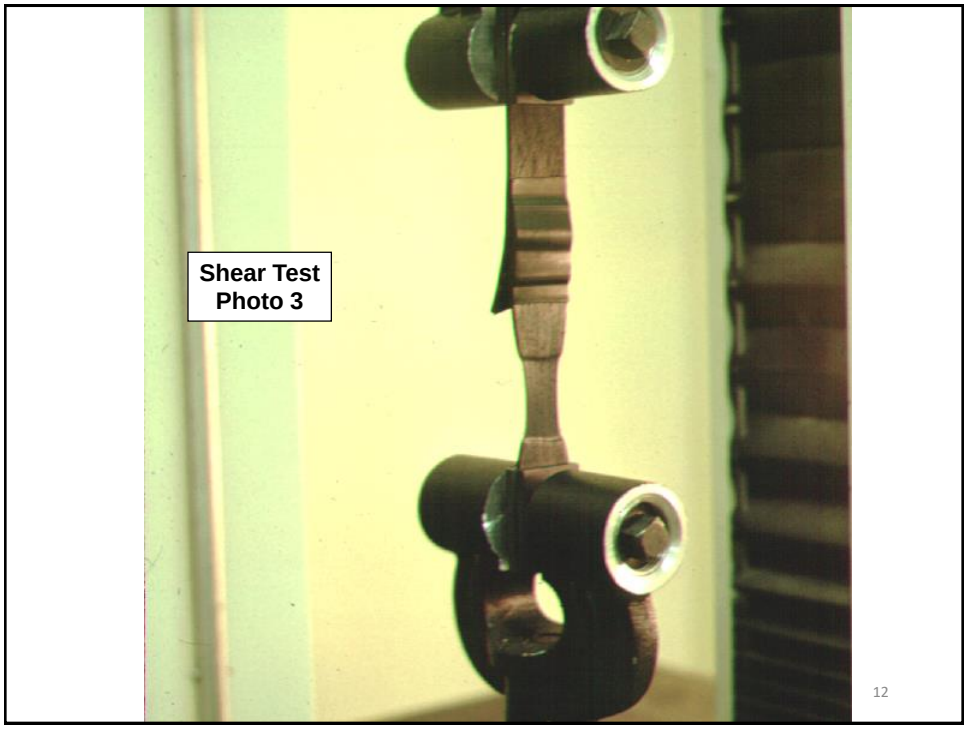

Shear Test
Photo 2
11


Shear Test
Photo 3
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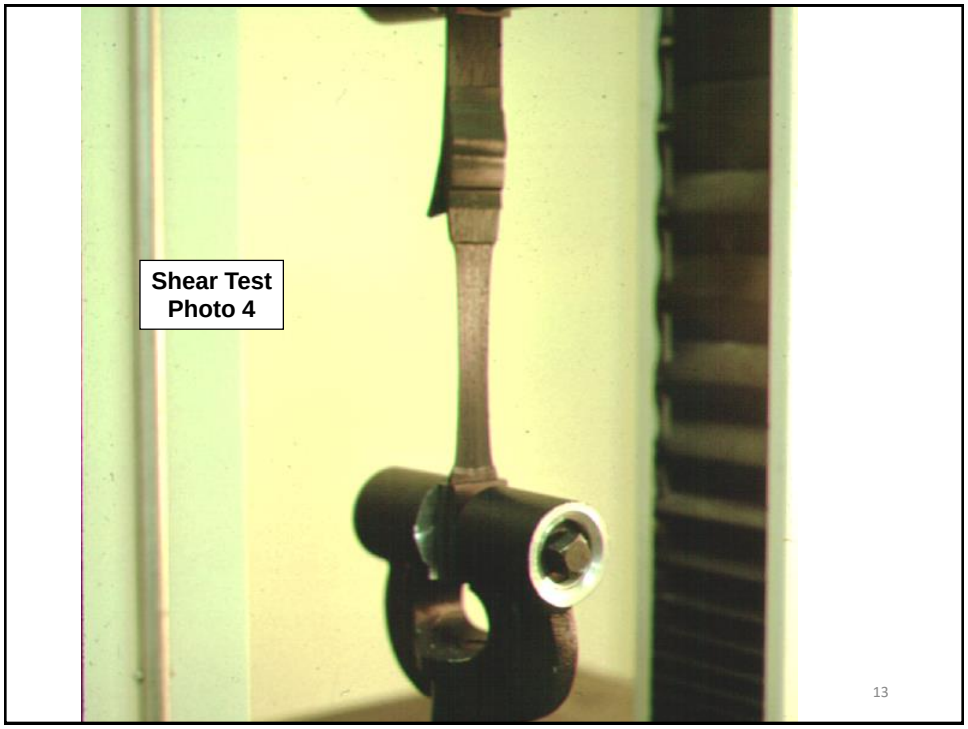

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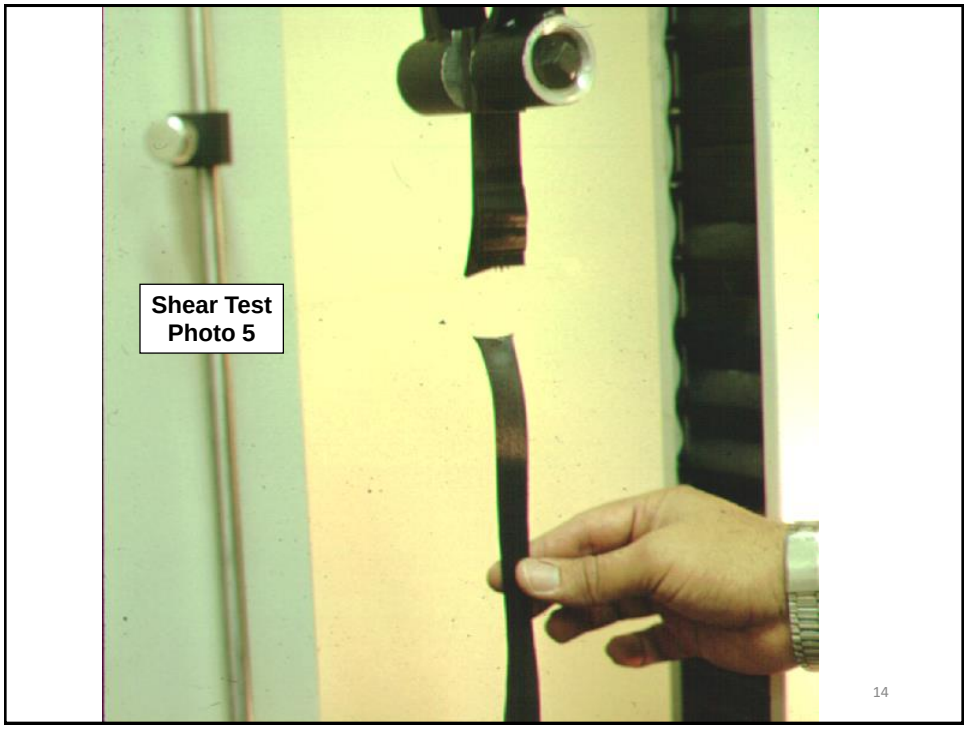

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Regarding Shear Elongation

$$E = \frac{L}{L_O}(100)$$

E = elongation (≥ 50% for all seams)

L = elongation at break

L_o = gage length (typ. 25 mm)

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Some Additional Details About Shear Testing

- speed 50 mm/min (2 in./min) for HDPE
  500 mm/min (20 in./min) for more flexible GMs
- both tracks of DTHW seams need to be tested individually by cutting through the air channel
- grip separation 50 mm (2 in.) plus seam width
- gauge length is 25 mm (1 in.)
- test is complete for HDPE at 50% elongation
- more flexible GMs need to be tested to failure

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Regarding Peel Testing

- 4/5 must ≥ spec table value
- outlier ≥ 80% spec table value
- tables values are percentages of sheet tensile strengths
- HDPE (~ 62%); LLDPE (~ 76%); fPP (~ 80%)
- peel test follows

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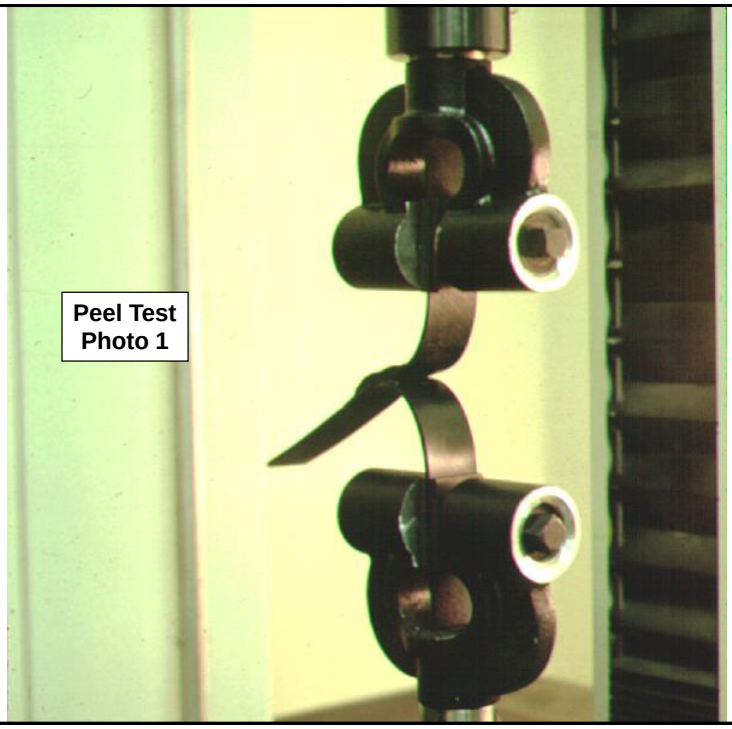

Peel Test Photo 1

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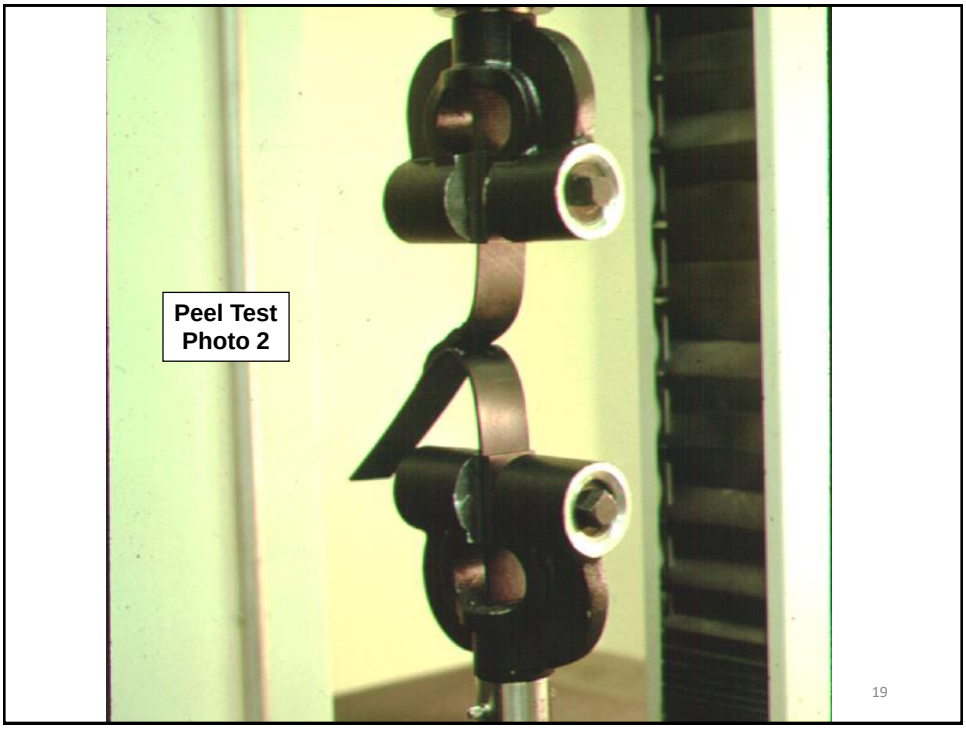

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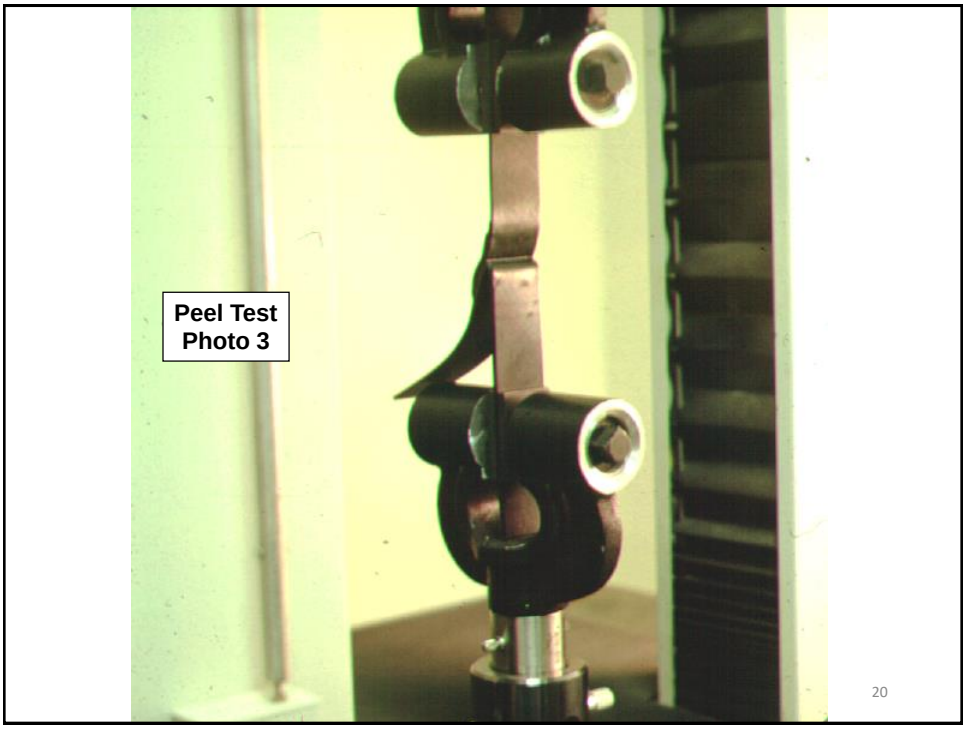

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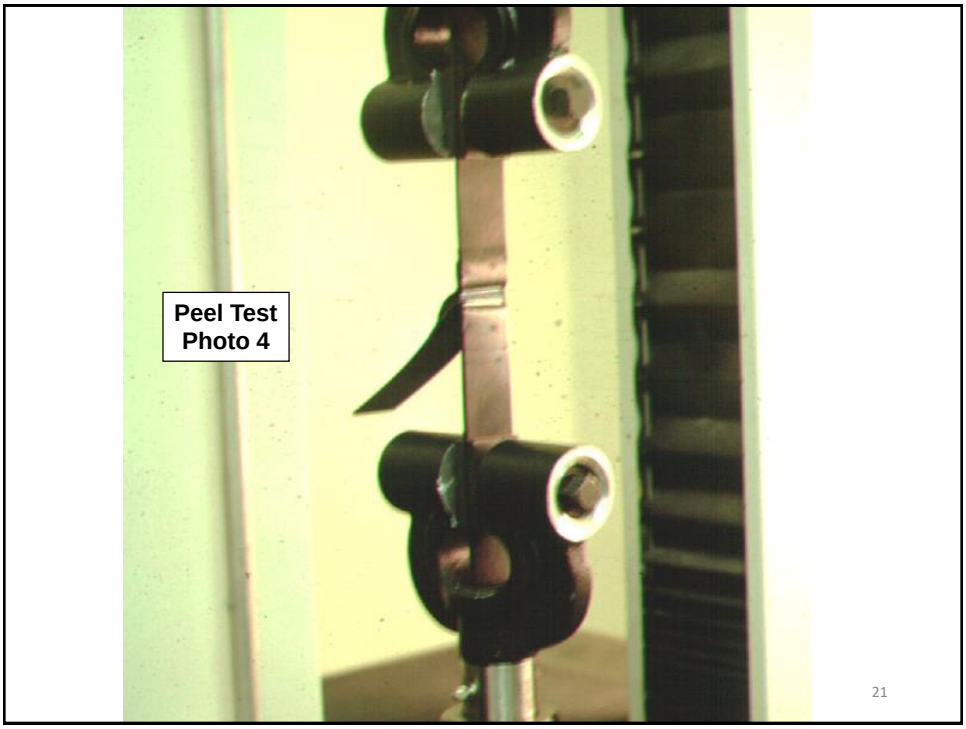
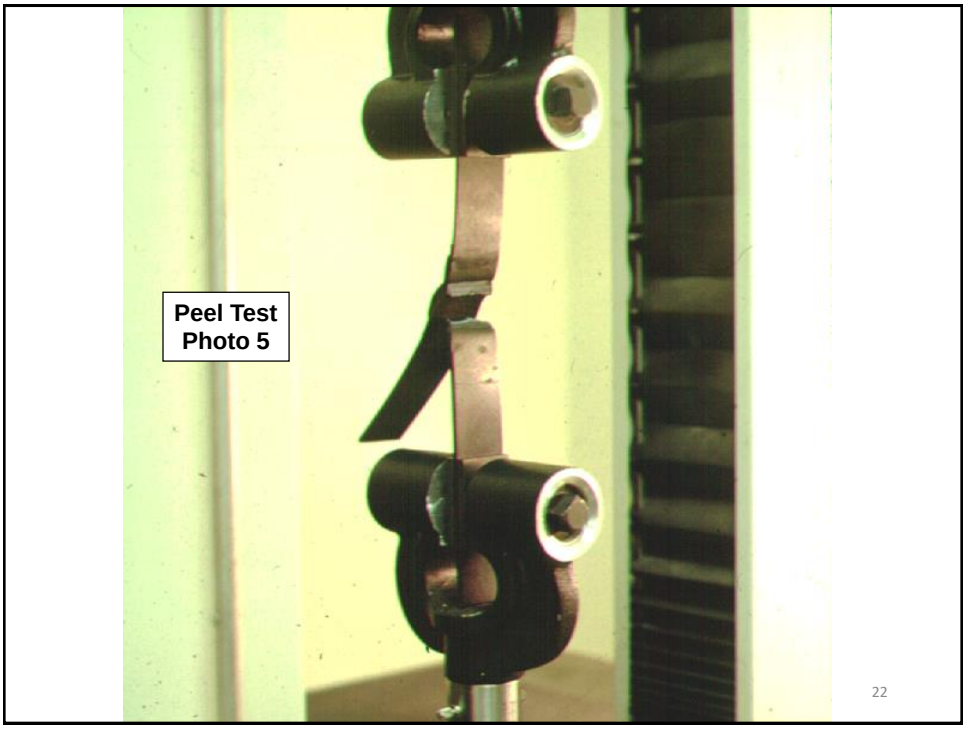

Peel Test
Photo 4
21


Peel Test
Photo 5
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Regarding Peel Separation

- also called peel “incursion”

$$S = \frac{A}{A_o}(100)$$

where

S = separation (≤ 25% for all seams)

A = average area of separation

A_o = original bonded area

- A and A_o are visual approximations
- tack weld and squeeze-out are not included
- differs from ASTM which states proportion of linear length not area as in this spec

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Some Additional Details

- speed 50 mm/min (2 in./min) for HDPE 500 mm/min (20 in./min) for more flexible GMs
- both DTHW seams are tested from outside in toward the air channel
- grip separation equals 50 mm (2 in.)
- estimate of separation is reported to the nearest 25%
- if grip separation is reduced it must be reported accordingly

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Locus-of-Break Patterns (Codes)

- following are unacceptable patterns
  - Hot Wedge AD & AD-Brk > 25%
  - Ext. Fillet AD1, AD2 & AD-WLD
    (unless strength is achieved)
- SIP is acceptable; it is sheet related

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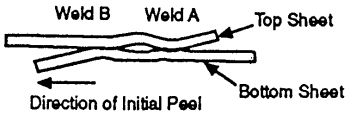
Unacceptable Hot Wedge Weld Breaks



Types of Break	Location of Break Code	Break Description
	AD	Adhesion Failure
	AD-BRK	Break in first seam after some adhesion failure. Break can be in either top or bottom sheet.

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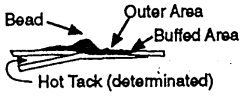
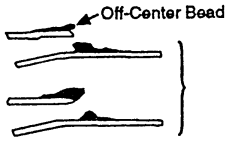
Unacceptable Extrusion Fillet Welds



Types of Break	Location of Break Code	Break Description
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.
	AD2	Failure in adhesion.
	AD-WLD(1)	Break through the fillet. (unless strength is achieved)

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Regarding SIP Failures

- separation-in-plane (SIP) is disconcerting
- generally occurs in peel testing
- can “travel” within sheet a considerable distance
- many opinions as to cause
- its sheet related; hence approved as far as seam spec is concerned

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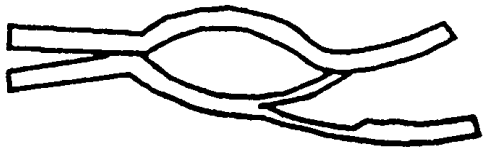
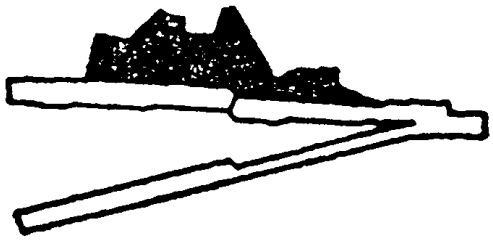


SIP in Dual Track Hot Wedge Seam



SIP in Extrusion Fillet Seam

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Concluding Comments

- spec addresses HDPE, LLDPE and fPP geomembrane seams
- accommodates smooth and textured homogeneous geomembranes
- (see GRI-GM19b for scrim reinforced geomembranes and barriers)
- silent on sheet manufacture method
- addresses hot wedge (single and dual track) and extrusion fillet seams
- if testing conducted in the field, shear elongation and peel separation can be eliminated and reported accordingly

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The Basic Tables Follow

HDPE – smooth and textured
LLDPE – smooth and textured
fPP – homogeneous

Note: The most recent version of this specification (text and tables) is available on the GSI Web Site <geosynthetic-institute.org>.

Table 1(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	39	52	65	78	104	130	156
peel separation, %	25	25	25	25	25	25	25

Notes for Tables 1(a) and 1(b):
1. Also for hot air and ultrasonic seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]							
shear strength[2], N/25 mm.	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], N/25 mm	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	170	225	285	340	455	570	680
peel separation, %	25	25	25	25	25	25	25

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rev. 1: 5/15/03

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]								
shear strength[2], lb/in.	30	45	60	75	90	120	150	180
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength[2], lb/in.	30	45	60	75	90	120	150	180
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

Notes for Tables 2(a) and 2(b):
1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]								
shear strength[2], N/25 mm	131	197	263	328	394	525	657	788
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength[2], N/25 mm	131	197	263	328	394	525	657	788
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], N/25 mm	95	150	190	250	290	385	500	595
peel separation, %	25	25	25	25	25	25	25	25

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Homogeneous Flexible Polypropylene (fPP) Geomembranes (English Units)

Geomembrane Nominal Thickness	30 mil	40 mil
Hot Wedge Seams[1]		
shear strength, lb/in.	25	30
shear elongation[2], %	50	50
peel strength, lb/in.	20	25
peel separation, %	25	25
Extrusion Fillet Seams		
shear strength, lb/in.	25	30
shear elongation[2], %	50	50
peel strength, lb/in.	20	25
peel separation, %	25	25

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Homogeneous Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.75 mm	1.0 mm
Hot Wedge Seams[1]		
shear strength, N/25 mm	110	130
shear elongation[2], %	50	50
peel strength, N/25 mm	85	110
peel separation, %	25	25
Extrusion Fillet Seams		
shear strength, N/25 mm	110	130
shear elongation[2], %	50	50
peel strength, N/25 mm	85	110
peel separation, %	25	25

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing