T-PEEL STRENGTH TESTING OF NEW TO OLD EPDM ROOF MEMBRANES

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The effect of bonding a new ethylene propylene diene terpolymer (EPDM) sheet to an existing EPDM roof is relatively unknown in terms of the strength of the lap seam. With increasing repairs to EPDM membranes, and use of new EPDM bonded to existing rubber at tie-in situations, the occasions to bond new membrane material to existing rubber roofs should increase. The objective of this study was to determine the T-peel strength of this type of bond and compare it with control sample strengths. T-peel tests were conducted on two sets of lap seams that were constructed in the field, bonding a new rubber sheet to existing EPDM that had been in place on a fully-adhered roof for about 10 years. A series of T-peel tests were then conducted on laboratory prepared samples, bonding new rubber to samples of the 10 year-old, fully-adhered EPDM, and samples of a 10 year-old, ballasted EPDM. The splice areas for the laboratory samples were prepared in the following manner: (1) water washed with a solution of water and commercial detergent, then solvent cleaned; (2) water and detergent washed only, and; (3) solvent cleaned. In order to provide a comparison with known strengths, control samples were fabricated in the laboratory using new rubber sheets and solvent cleaning in accordance with manufacturers directions. The adhesive used to bond the rubber sheets was a butyl-based adhesive. The T-peel strengths of the new to old EPDM laps were then compared to the control samples and T-peel strengths of new to old seams fabricated in the field.

KEYWORDS

EPDM, T-peel test, lap seam, adhesion, cohesion, butyl, aged, weathered, fully adhered, ballasted.

INTRODUCTION

Surface deterioration of single-ply roof membranes is inevitable, even for membranes that are considered protected. The effects of heat, sun, moisture, dirt, movement and many other factors work to change the surface characteristics of a membrane sheet. Some effects penetrate well beyond the surface, and effect the material properties of the membrane.

Over the last 15 years, ethylene propylene diene terpolymer (EPDM) membrane material has been installed in many more roof applications than any other single-ply sheet material. One of the reasons for EPDM's popularity is its relative inert nature and resistance to weathering. EPDM (rubber) roof applications include fully-exposed membranes in mechanically fastened and fully-adhered applications, and in protected, ballasted applications. Even in a ballasted configuration, rubber sheets are exposed to the effects of solvents and chemicals deposited from rainfall or manmade sources, from silt and other materials washed from the ballast, to direct sunlight in areas of sparse coverage, repairs, or wind damage and severe membrane movement.

Since millions of square feet of EPDM sheet materials have been in place for a number of years, we are now reaching the time when significant repairs and adhesive bonding to large areas of new membrane to existing rubber sheets may be required. Patching rubber sheets due to damage has long been of concern to those involved in making repairs to rubber roofs. In the repair and patching process, care must be taken to assure that the effects of bonding a new rubber sheet to an aged and weathered sheet are taken into consideration.

In discussing patching procedures with contractors that are involved with the repair process, it is apparent that additional steps are routinely taken to assure adequate cleaning and removal of surface contaminants from aged, weathered rubber. These steps normally go beyond the typical manufacturers recommendations for new rubber seams, in order to start with as clean a surface as possible. The most common method cited for repairing a patch or tie-in area is to scrub the existing surfaces of the splice area with a solution of detergent and water, rinse thoroughly, allow the rubber to dry, then follow the membrane and adhesive manufacturers specifications for fabricating the field seam.

This study focuses on the effect of surface cleanliness of new to old EPDM adhesive bonds for rubber sheets that have been in service for about 10 years. T-peel strength is the measured parameter. Although T-peel strength is not necessarily a comprehensive indicator of overall seam performance, it has been shown to be a good indicator of the effectiveness of surface preparation. In this study, rubber from two in-service roofs was used to evaluate the effectiveness of different cleaning techniques on the old rubber. Rubber from a 10 year-old, fully-adhered roof, and a 10 year-old, ballasted roof were tested.

The old membrane material from the fully-adhered roof showed no signs of deterioration to the naked eye. Further laboratory analysis beyond the scope of this study would be required to study subsurface or microscopic effects of aging. The old membrane material from the ballasted roof was visibly dirty and stained from its 10 years of use.

TEST SAMPLE FABRICATION

Test samples for T-peel testing were fabricated in the field and in the laboratory. The initial field samples were fabricated at a project which involved significant repairs to an existing, 10 year-old, fully-adhered rubber membrane. The repairs consisted of tear-off and replacement of large sections of the roof and installation of crickets over the old membrane. Both situations required bonding new EPDM to aged, weathered rubber.

Laboratory samples were later prepared by adhesively

bonding new EPDM to the old rubber samples taken from the same 10 year-old, fully-adhered roof, and from a 10 year-old, ballasted roof. The laboratory samples were prepared utilizing several cleaning techniques.

T-peel testing for all of the samples was conducted in general accordance with ASTM D 1876. After the samples were fabricated in approximate 30cm to 60cm (1 to 2 feet) long sections with a 10cm (4 inch) wide lap, they were allowed to cure for a minimum of seven days in the laboratory at 23 ± 2°C (73 ± 3°F) and 40 to 50 percent relative humidity. The seams were then cut into 25mm (1 inch) wide strips for testing. Five strips were tested for each age and condition. The results presented in this study represent the average T-peel strength of five strips. T-peel testing was conducted at a machine cross-head speed of 50mm (2 inches) per minute. The force required to separate the rubber was measured over an approximate 50mm to 75mm (2 to 3 inches) of seam and averaged over the five specimens.

Fabrication of the samples was conducted in general accordance with the rubber and adhesive manufacturers recommendations. Coverage rate for the adhesive was verified for the laboratory samples by pre-weighing the adhesive for the specified seam lengths, to conform with the manufacturers minimum coverage rates. The bonding adhesives used for both the field and laboratory portions of the study were butyl-based adhesives.

Splice area preparation techniques were varied to meet the objectives of the study. Preparation techniques were as follows:

- Water Cleaned (WC)—Splices were prepared by cleaning both mating surfaces of the rubber by scrubbing with a stiff bristle brush and a solution of detergent (sodium tripolyphosphate) in warm water.
- Solvent Cleaned (SC)—These samples were prepared by cleaning the mating surfaces of the rubber with a clean rag soaked in hexane, in general accordance with manufacturers recommendations.
- Water and Solvent Cleaned (WSC)—These splices were prepared by cleaning both mating surfaces of the rubber with a stiff bristle brush and solution of detergent in warm water. After the mating surfaces dried, they were cleaned with a clean rag soaked in hexane.

FIELD SEAM PREPARATION

Initial field testing was conducted to provide an assessment of cleaning techniques on a roof involving bonding new rubber to a 10 year-old EPDM surface. Seam preparation consisted of water and solvent cleaning both mating surfaces of the rubber. Table 1 summarizes the membrane data and results of T-peel testing of two sets of field prepared seams. Average T-peel strength was about 0.5 to 0.7 kN/m (3 to 3.9 lbf/in.). These specimens failed in the adhesive mode, indicating that a surface effect controlled the failure mechanism. A well bonded seam would generally be expected to fail in the cohesive mode, occurring when separation of the EPDM strips occurs in the adhesive itself. Adhesive failure occurs when the adhesive separates cleanly from one of the rubber surfaces, indicating that cleaning may not have removed all of the contaminants. Further visual assessment of the field samples indicated the presence of a white residue, apparently a result of incomplete rinsing of the detergent during water cleaning. The presence of this residue, and the failure mode observed appear to explain the relatively low T-peel strength of the field prepared samples.

LABORATORY SEAM PREPARATION

Three sets of lap seams were prepared in the laboratory. New rubber material from two different manufacturers were bonded to samples of the 10 year-old rubber taken from the fully-adhered roof (samples Lab A and Lab B). A third set of lap seams were fabricated in the laboratory using new rubber from the same manufacturer as the new rubber from set Lab B. This new rubber was bonded to samples of the 10 year-old rubber taken from the ballasted roof (sample set Lab B1).

In order to provide a reference datum for seam strength, samples of the new rubber from the two manufacturers represented were fabricated by solvent cleaning the splice area and forming seams of new rubber to new rubber. These samples were designated as control samples (Lab A/Control, Lab B/Control, Lab B1/Control).

In forming the seams for new rubber bonded to old rubber, three different cleaning techniques which were previously described were used. The first technique involved water and detergent cleaning the mating surfaces (designated WC). The second technique involved solvent cleaning the mating surfaces (designated SC). The third technique involved both water and solvent cleaning (designated WSC).

Table 2 summarizes the membrane data and T-peel test results for the new rubber (manufacturer A) bonded to the old rubber from the 10 year-old, fully-adhered roof. T-peel strength ranged from 0.91 kN/m (5.2 lbf/in.) for water cleaning to 1.07 kN/m (6.1 lbf/in.) for water and solvent cleaning. T-peel strength for solvent cleaning (only) fell between those two values at 0.99 kN/m (5.7 lbf/in.). The control sample showed the highest strength at seven days at 1.29 kN/m (7.4 lbf/in.).

The data indicate that the effectiveness of cleaning is increased over strictly solvent or water when both water and solvent cleaning are used together. In this case, the water and solvent cleaned samples achieved strengths of about 83 percent of the control samples. An apparent anomaly in the data is that the water and solvent cleaned samples failed in the adhesive mode, even though the strength was slightly higher than the solvent cleaned samples, which failed in the cohesive mode. Adhesive failure in the water cleaned (only) samples might be expected.

Table 3 summarizes the membrane data and T-peel strength results for the new rubber (manufacturer B) bonded to the old rubber from the 10 year-old, fully-adhered roof. T-peel strength ranged from 1.21 kN/m (6.9 lbf/in.) for water cleaning to 1.47 kN/m (8.4 lbf/in.) for water and solvent cleaning. As was the case with manufacturer A, the strength of the solvent cleaned samples fell between the other values at 1.35 kN/m (7.7 lbf/in.). The T-peel strength of the control sample was 1.30 kN/m (7.5 lbf/in.).

The water and solvent cleaned samples gained the highest strength of the set, at about 113 percent of the control sample. This data also indicates that the effectiveness of cleaning is increased when both water and solvent is used, even to the point where T-peel strengths greater than the new to new EPDM bonds can be achieved. As we would expect, the failure mode for the solvent cleaned, water and solvent

cleaned, and control samples failed in the cohesive mode. The water cleaned samples failed in the adhesive mode.

Table 4 summarizes the membrane data and T-peel strength results for the new rubber (manufacturer B) bonded to the rubber from the 10 year-old, ballasted roof. T-peel strength ranged from 0.72 kN/m (4.1 lbf/in.) for water cleaning to 1.20 kN/m (6.8 lbf/in.) for water and solvent cleaning. In this case, the T-peel strength of the solvent cleaned samples was below that of the water cleaned samples. In preparing the surface of the 10 year-old, ballasted membrane, it was apparent that the dirt and surface contaminants were much better adhered and harder to remove than the fully-adhered membrane. The scrubbing action of a stiff bristle brush was apparently more effective in removing surface dirt and contaminants than cleaning with solvent alone.

The T-peel strength of the control sample was 1.30 kN/m (7.5 lbf/in.). The water and solvent cleaned samples achieved about 92 percent of the T-peel strength of the control samples. It is also apparent that the overall cleaning effort was not as effective in achieving T-peel strengths comparable to control (compared to the fully-adhered samples) when only water or solvent cleaning was used. All of the samples prepared by bonding new rubber to the old, ballasted membrane failed in the adhesive mode, also indicating that cleaning was not as effective as with the fully-adhered or control samples.

SUMMARY

Although EPDM is one of the more weather resistant and durable single-ply roof products, the effect of 10 or more years of weathering and gathering of dirt and contaminants can have a significant effect on the seam strength of any new rubber bonded to it. In applications of seaming new rubber to aged rubber, surface cleaning becomes more critical than in new rubber seams.

It is generally recognized that one of the common steps taken to prepare aged rubber is to wash the splice area thoroughly, and just as important, to rinse the membrane thoroughly. The seam can then be prepared by solvent washing and following the manufacturers directions for fabricating a new seam.

The initial field testing in this study was done by preparing small sections of seam in the field. However, large quantities of water were not made available to rinse the detergent-washed seams. Although the presence of the detergent residue may not have been the only factor reducing the T-peel strength of the seam, the residue appears to have negatively affected the strength of the seam. The low peel strength and the adhesive failure mode are strong indicators of the effect of the residue.

The T-peel strength of the field prepared seams was only about 0.5 to 0.7 kN/m (3 to 4 lbf/in.), as compared to T-peel strengths of 1.0 to 1.2 kN/m (6.1 to 6.8 lbf/in.) achieved by water and solvent cleaning the new rubber bonded to the 10 year-old, fully-adhered roof membrane and the ballasted roof membrane.

Figure 1 was prepared to compare the T-peel strengths of the laboratory prepared samples to the control samples (new rubber to new rubber). For each set, increases in T-peel strength were observed in proceeding from water cleaning only, to both water and solvent cleaning. T-peel strengths comparable to control were observed for water and solvent cleaned samples for all three sets. The percentage of control strength varied from just over 80 percent to well over 100 percent.

Another observation that can be made is that for ballasted roofs, cleaning is more difficult due to the level of dirt and contaminants on the membrane. Water cleaning only and solvent cleaning only were effective in achieving only about 50 to 55 percent of control strength. Water and solvent cleaning was effective in achieving about 92 percent of control strength for the new rubber to ballasted EPDM samples. In summary, the following observations can be made:

- Thorough rinsing of detergent-washed, aged rubber is required in order to remove all of the detergent residue.
- Water washing with a stiff bristle brush and a solution of detergent in warm water is an effective cleaning technique prior to solvent cleaning the splice area.
- T-peel strengths comparable to those of new EPDM seams can be achieved by bonding new rubber to aged, weathered EPDM.
- Ballasted EPDM roofs are harder to clean and prepare for new rubber than other, exposed rubber membranes such as fully- adhered and mechanically-fastened systems.

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Membrane Data		
Set No:	**F1**	**F2**
Sample Type:	New to Old Rubber	New to Old Rubber
Seam Preparation:	Water & Solvent (WSC)	Water & Solvent (WSC)
Age When Tested:	7 days	8 days
Rubber Thickness mm(mils):	1.5 (60)	1.5 (60)
T-Peel Test Data		
Average Strength kN/m (lbf/in.):	0.68 (3.90)	0.53 (3.03)
Range kN/m (lbf/in.):	0.60—0.75 (3.4—4.3)	0.51—0.63 (2.9—3.6)
Standard Deviation kN/m (lbf/in.):	0.08 (0.43)	0.08 (0.43)
Coefficient of Variation (%):	11.0	14.9
Average Adhesive Thickness mm(mils):	0.38 (15.1)	0.22 (8.7)
Primary Failure Mode:	Adhesive	Adhesive

Table 1 *Field prepared samples—new rubber to 10-year-old, fully-adhered EPDM (Manufacturer A)*

Membrane Data				
Sample No:	Lab A/Control	Lab A/WSC	Lab A/SC	Lab A/WC
Sample Type:	New to New Rubber	New to Old Rubber	New to Old Rubber	New to Old Rubber
Seam Preparation:	Solvent Cleaned (SC)	Water & Solvent (WSC)	Solvent Cleaned (SC)	Water Cleaned (WC)
Age When Tested:	7 days	7 days	7 days	7 days
Rubber Thickness New/Old mm(mils):	1.5 (60)	1.5 (60)	1.5 (60)	1.5 (60)
T-Peel Test Data				
Average Strength kN/m (lbf/in.):	1.29 (7.36)	1.07 (6.10)	0.99 (5.66)	0.91 (5.18)
Range kN/m (lbf/in.):	1.17—1.42 (6.7—8.1)	0.87—1.35 (5.0—7.7)	0.74—1.19 (4.2—6.8)	0.81—1.14 (4.6 6.5)
Standard Deviation: kN/m (lbf/in.):	0.11 (0.64)	0.19 (1.08)	0.17 (0.95)	0.15 (0.83)
Coefficient of Variation (%):	8.7	17.7	16.7	16.0
Average Adhesive Thickness mm(mils):	0.30 (11.8)	0.15 (6.0)	0.22 (8.8)	0.21 (8.2)
Primary Failure Mode:	Cohesive	Adhesive	Cohesive	Adhesive

Table 2 *Laboratory prepared samples—new rubber to 10-year-old, fully-adhered EPDM (Manufacturer A)*

Membrane Data				
Sample No:	Lab B/Control	Lab B/WSC	Lab B/SC	Lab B/WC
Sample Type:	New to New Rubber	New to Old Rubber	New to Old Rubber	New to Old Rubber
Seam Preparation:	Solvent Cleaned (SC)	Water & Solvent (WSC)	Solvent Cleaned (SC)	Water Cleaned (WC)
Age When Tested:	7 days	7 days	7 days	7 days
Rubber Thickness mm(mils):	1.5 (60)	1.5 (60)	1.5 (60)	1.5 (60)
T-Peel Test Data				
Average Strength kN/m (lbf/in.):	1.30 (7.46)	1.47 (8.42)	1.35 (7.70)	1.21 (6.94)
Range kN/m (lbf/in.):	1.22—1.42 (7.0—8.1)	1.22—1.73 (7.0—9.9)	1.14—1.61 (6.5—9.2)	0.95—1.45 (5.4—8.3)
Standard Deviation: kN/m (lbf/in.):	0.08 (0.47)	0.20 (1.17)	0.19 (1.11)	0.24 (1.30)
Coefficient of Variation (%):	6.3	13.9	14.5	19.9
Average Adhesive Thickness mm(mils):	0.25 (10.0)	0.24 (9.6)	0.35 (14.0)	0.32 (12.4)
Primary Failure Mode:	Cohesive	Cohesive	Cohesive	Adhesive

Table 3 Laboratory prepared samples—new rubber to 10-year-old, fully-adhered EPDM (Manufacturer B)

Membrane Data				
Sample No:	Lab B1/Control	Lab B1/WSC	Lab B1/SC	Lab B1/WC
Sample Type:	New to New Rubber	New to Old Rubber	New to Old Rubber	New to Old Rubber
Seam Preparation:	Solvent Cleaned (SC)	Water & Solvent (WSC)	Solvent Cleaned (SC)	Water Cleaned (WC)
Age When Tested:	7 days	7 days	7 days	7 days
Rubber Thickness New/Old mm(mils):	1.5/1.5 (60/60)	1.5/1.1 (60/45)	1.5/1.1 (60/45)	1.5/1.1 (60/45)
T-Peel Test Data				
Average Strength kN/m (lbf/in.):	1.30 (7.46)	1.20 (6.84)	0.67 (3.80)	0.72 (4.10)
Range kN/m (lbf/in.):	1.22—1.42 (7.0—8.1)	1.05—1.35 (6.0—7.7)	0.52—0.79 (3.0—4.5)	0.63—0.84 (3.6 4.8)
Standard Deviation: kN/m (lbf/in.):	0.08 (0.47)	0.13 (0.74)	0.10 (0.56)	0.10 (0.56)
Coefficient of Variation (%):	6.3	10.8	14.6	13.8
Average Adhesive Thickness mm(mils):	0.25 (10.0)	0.15 (6.0)	0.15 (6.0)	0.24 (9.4)
Primary Failure Mode:	Cohesive	Adhesive	Adhesive	Adhesive

Table 4 Laboratory prepared samples—new rubber to 10-year-old, ballasted EPDM (Manufacturer B)

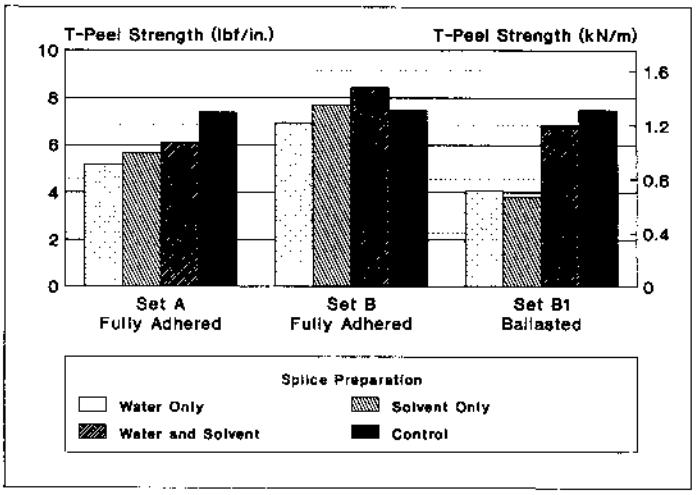

Figure 1 *Comparison of laboratory—cleaned T-Peel strength to control.*