INVESTIGATION OF UNIVERSAL REPAIR PROCEDURES FOR SINGLE-PLY ROOFING SYSTEMS

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The U.S. Navy has shore facilities located all over the world. Facilities located in remote areas long distances from the continental U. S. present special logistic problems relative to materials for repair and maintenance of roofing systems. Some facilities have as many as 15 to 20 different roofing systems, including most of the different generic types of single-ply roofing systems (SPRS). It is impossible for these facilities to stock all of the different types of materials required to repair or patch these different roofing systems as recommended by the system suppliers. This is particularly true with respect to the SPRS where the patching materials have short shelf lives.

The Naval Civil Engineering Laboratory was requested by the Northern Division of the Naval Facilities Engineering Command to investigate the potential for development of one or two patching systems that could be utilized as 'universal repair methods' for the SPRS.

SPRS membranes investigated included EPDM, PVC, modified PVC, CSPE, CPE and PIB. The T-peel strengths of these membranes and various seam adhesive systems were determined for purposes of comparison. These included: the seam adhesive recommended by the membrane manufacturer, a two component neoprene contact adhesive, off-the-shelf contact adhesive and butyl seam tapes. In addition, two acrylic elastomeric coatings reinforced with polyester/glass scrim were applied and tested for T-peel strength as a patching system.

Data are presented on results of the T-peel tests for the different combinations of patching systems investigated to date. These data together with environmental considerations were used in selecting potential universal repair procedures for further studies. The initial phase of the investigation suggests that a butyl seam tape and EPDM membrane may be the best materials for patching single-ply roofing membranes (SPRM), while an EPDM adhesive and EPDM membrane for repairing EPDM, CSPE and PIB membranes, and PVC membrane for heat welding PVC, modified PVC and CPE membranes also merit additional study.

KEYWORDS

Chlorinated polyethylene (CPE), chlorosulphonated polyethylenes (CSPE), EPDM, polyisobutylene (PIB), polyvinyl chloride (PVC), single-ply roofing systems, universal repair procedures.

INTRODUCTION

Single-ply roofing systems (SPRS) have been widely used as alternative roofing systems over the past 10 years and now account for about half of all low-slope roofing installed.[1] As these roofs age, when they become damaged or when changes are made on the roof, it is necessary to patch or repair the aged or damaged membrane. As in the case of seams, the required function of patches or repairs is to maintain the watertight integrity of the single-ply roofing system.

The major SPRS in use today can be classified into about six different generic types, and there are a number of different systems manufactured or marketed by different companies within each generic type. In all, there are well over 200 different single-ply roofing membranes available. There are almost as many repair systems. Although repair procedures for similar materials are similar, there are no standardized procedures or materials, even within a given generic type. Each company recommends repair systems that are specific for, and use, their products. The Army Construction Engineering Research Laboratory has developed generic repair procedures for each of the different generic types, but these have not become standardized within the industry.[2]

BACKGROUND

The U.S. Navy has shore facilities located all over the world. Facilities located in remote areas long distances from the continental U.S. present special logistic problems relative to materials for repair and maintenance of roofing systems. Some facilities have as many as 15 to 20 different types of roofing systems including most of the different generic types of SPRS. It is impossible for these facilities to stock all of the different types of materials required to repair or patch these different roofing systems as recommended by the system suppliers. This is particularly true with respect to the SPRS where many of the patching materials, such as the seam adhesives, may have relatively short shelf lives. This suggested a need for a method or methods that could be used to patch several different generic types of SPRS.

The Naval Civil Engineering Laboratory was requested by the Northern Division of the Naval Facilities Engineering Command to investigate the potential for development of criteria for one or two patching systems that could be utilized as "universal repair methods" for the SPRS.

SCOPE OF WORK

The different generic types of SPRS membranes included in this initial phase of the investigation consisted of four ethylene-propylene-diene terpolymers (EPDM), three chlorosulphonated polyethylenes (CSPE), two polyvinyl chlorides (PVC), one modified polyvinyl chloride (mod. PVC), one chlorinated polyethylene (CPE) and one polyisobutylene (PIB). Except for those that were heat welded, each of the systems also included the manufacturers recommended seam adhesives. In addition, two seam tapes were included in the program.

In this initial phase of the work, a number of different seaming materials and procedures were investigated. This included investigation of different membrane cleaning procedures prior to application of the adhesives and, where available, each manufacturer's adhesive was used on their membrane to establish a baseline value. One of the better seam adhesives for the EPDM was used on the other generic types to determine its potential, and two other adhesive systems were tested to determine their usefulness in universal repair systems. Seaming tapes were also investigated and results compared to those obtained using the adhesives. Finally, scrim reinforced coating materials were investigated as a universal repair system. This first phase of the work did not investigate potential problems associated with the long-term compatibility of different materials that might be in contact with one another.

EXPERIMENTAL

Specimen Preparation

The effectiveness of the patching methods were determined in the laboratory by adhering two membrane samples together using the various seaming procedures under investigation, and determining the T-peel strength of the resultant seam (generally in accordance with ASTM D 1876). In addition, acrylic elastomer coatings reinforced with a polyester/fiberglass scrim were also applied to one piece of some of the SPRS membranes as an alternative patching method, and the T-peel strength of this coating membrane determined.

For each of the SPRS membrane materials, two samples 229mm by 305mm (9 in. by 12 in.) rather than the 152mm by 305mm (6 in. by 12 in.) samples specified by ASTM D 1876, were cut from the membrane roll and generally cleaned according to one of two primary procedures. Procedure 1 consisted of flooding the membrane with solvent grade hexane and vigorously rubbing and wiping the membrane with a clean, soft cloth. This procedure was then repeated two additional times. Procedure 2 consisted of flooding the membrane with hexane, vigorously scrubbing the membrane with a stainless steel scrubbing pad, and wiping with a soft, clean cloth. Procedure 2 was also repeated two additional times with each sample. Both of these procedures are widely used in the field. In a few cases, solvent grade xylene was substituted for the hexane used as the cleaning solvent particularly with the Hypalon (CSPE) membranes. In another case, the EPDM membrane was scrubbed with a steel wool soap pad and water in-lieu-of the hexane.

The majority of sample preparation was carried out using Procedure 2. In all cases, the cleaned samples were allowed to dry thoroughly and the adhesive, seam tape, seam primer and tape, or scrim reinforced acrylic elastomer coatings were applied in accordance with the procedures given below.

The adhesives were applied by flowing on with a full brush to a 152mm by 305mm (6 in. by 12 in.) area of the cleaned side of each of the membrane pieces and allowed to set until tacky, generally 15 to 30 minutes (for this paper, this open time is referred to as "long open time"). The two coated surfaces were then rolled together and within five minutes, pressed together in a hydraulic press at 0.69 MPa (100 lbf/in.^{2}) for five seconds.[3] In a few cases, generally with membranes other than EPDM, the two pieces were placed together immediately after application of the adhesive (for this paper, this open time is referred to as 'short open time'). After the two pieces were bonded together, they were cured for one week under ambient laboratory conditions prior to testing.

The seam tapes were applied in two strips across the 305mm (12 in.) width of one of the cleaned surfaces of the two membrane pieces. In some cases, the cleaned membrane surfaces were primed, the primer allowed to dry, and the tape applied as described above. The second piece of cleaned membrane was then rolled onto the tape, pressed together by hand and then pressed together for five seconds in the hydraulic press at 0.69 MPa (100 lbf/in.^{2}). The bonded pieces were allowed to set at ambient laboratory conditions for one week prior to testing.

The scrim-reinforced coating patches were prepared by first applying a full coat of the acrylic elastomer coating to a 152mm by 305mm (6 in. by 12 in.) cleaned surface area of one piece of membrane and allowed to dry for one hour. A second coat was then applied to the 152mm by 305mm (6 in. by 12 in.) area and a 229mm by 305mm (9 in. by 12 in.) piece of polyester/fiberglass scrim was embedded in the wet coating and allowed to dry for 24 hours. A third coat of acrylic elastomer coating was then applied to the coated scrim and the applied system allowed to dry for one week under ambient laboratory conditions prior to T-peel testing.

Specimen T-Peel Testing

After the adhered or coating patched samples had cured for one week, they were cut into 25mm (1 in.) wide by 229mm (9 in.) long specimens for T-peel tests. T-peel tests were conducted in accordance with ASTM D 1876 except that the crosshead speed was 50mm (2 in.)/min. rather than 254mm (10 in.)/min.[11], and five rather than ten specimens were tested for each sample. T-peel tests were conducted using an Instron Model 1122 test machine.

RESULTS AND DISCUSSION

Problems with single-ply roofing systems have in the past, and continue to be related to seam failures.[1] It would be expected that the seams would also represent a potential problem with repair procedures especially where the seams are made using adhesives or tapes with vulcanized (cured) membranes. Because of the potential problems with seams opening up and permitting leaking of single-ply roofing membranes, a great deal of research has been conducted on the seams.[3-12] With the EPDM membranes, seam problems have been associated at least in part with cleanliness (absence of talc), and this factor has been investigated in detail by the National Institute of Standards and Technology (NIST).[9,11]

Results of the testing are presented in Tables 1 through 6. These tables present the T-peel strengths as well as the standard deviation (STD) and coefficient of variation (COV) for each of the sets of samples analyzed. The nature of the work did not permit a full statistical analysis, and, as a result, comparisons are made on the basis of average T-peel strengths.

Table 1 presents the T-peel seam strengths of samples, using the manufacturer's recommended adhesive. Most of these are EPDM membranes, but two CSPE and one PIB membrane were also included.

Seam problems have not been as troublesome with the thermoplastic membranes where the patches are normally either heat or solvent welded to the existing membranes. No heat welded samples were included in this phase of the research.

Specimen numbers 1-3 versus 4 (Table 1) provide a comparison between cleaning Procedures 1 and 2 for EPDM-1 membrane, showing that Procedure 2 (hexane, stainless steel pad, cloth) appears to provide a somewhat higher seam strength than cleaning Procedure 1 (hexane, cloth). Viewing these cleaned seams under a microscope showed that samples cleaned using Procedure 2 had little or no talc present while those cleaned using Procedure 1 showed isolated specs of talc remaining. The amount of talc on the samples was not quantified as in reference 9.

The opposite is true for EPDM-2 and 3, Specimens 7-8 and 9-10, respectively, where cleaning Procedure 1 rather than Procedure 2 provided a significantly higher T-peel strength. The reason for this reversal is not understood and time did not permit rerunning these samples during this phase of the tests.

A comparison of some other membrane cleaning methods with EPDM-1 were tested using Specimens 4, 5 and 6. Specimen 4 used cleaning Procedure 2, Specimen 5 was cleaned by scrubbing with a steel wool soap pad and water (no hexane wash), and Specimen 6 was first scrubbed with a stiff bristled brush, soap and water to remove most of the talc followed by further scrubbing using cleaning Procedure 2. Results suggest that cleaning Procedure 2 provides stronger T-peel strengths than either of these methods.

With EPDM-1, both a short open time, Specimen 2, and additional stirring of the adhesive, Specimen 3, provided a slight increase in the T-peel strength over Specimen 1. Additional stirring of the adhesive included stirring by hand with a paddle as well as shaking, as was done with most of the mixing.

Manufacturers recommended adhesive for the CSPE-1 and CSPE-2 samples, Specimens 12 and 13, respectively, provided strong T-peel strengths. In both cases, failure occurred in the membrane (delamination in the scrim) rather than in the adhesive bond as with the EPDMs. This is not surprising since at this stage, the CSPE is uncured and some solvent welding may have taken place. Cleaning of the membrane with xylene before adhesive application with Specimen 13 appeared to enhance the T-peel results. Finally, failure of the PIB-1, Specimen 14 also occurred in the membrane when the manufacturer's adhesive was used which again appears to be solvent welding of the PIB thermoplastic membrane.

The next set of experiments involved using the recommended adhesive for EPDM-1 on different generic types of membranes other than EPDM. Results are given in Table 2.

The EPDM-1 T-peel results given in Table 2, Specimen 15, is also listed in Table 1 as Specimen 4 and is listed here for ready comparison with results obtained from other generic types of membranes. The three CSPEs tested with the EPDM-1 adhesive gave differing results. Specimens 16 and 18 gave somewhat lower results while Specimen 17 provided relatively good T-peel strengths. This appears to be due principally to the xylene wash given to Specimen 17 prior to adhesive application.

The two PVC membranes showed very low T-peel strengths. These low results suggest that use of EPDM-1 seam adhesive is not acceptable for the PVC membranes using these particular procedures for cleaning and making the seam.

T-peel results obtained with the modified PVC (PVC Alloy) and the CPE, Specimens 21 and 22, respectively, were very similar but somewhat lower than desirable. Washing the PVC, modified PVC and CPE membranes with solvents other than hexane may enhance the T-peel results. The PIB membrane, Specimen 23, provided good results with the EPDM-1 adhesive in that failure occurred in the membrane rather than in the bond in all cases.

The third procedure investigated involved special two component neoprene adhesives for seaming EPDM and CSPE membranes. Results are given in Table 3. Results for all EPDM membranes were quite low and certainly not acceptable for seaming this type of membrane. Results for the three CSPE membranes show that a xylene wash in-lieu of hexane enhances the T-peel strength of samples made with similar adhesives, Specimens 29 and 31, versus Specimen 30. In the case of Specimen 30, material failure occurred, rather than adhesive failure as with Specimens 29 and 31. Because of the poor results with the EPDM membranes, testing of this adhesive system with other membranes was not pursued.

A conventional contact neoprene cement was investigated as a possible seam adhesive to use with the different membranes in the fourth procedure. This type adhesive was included in the investigation because such materials are generally readily available in most Navy locations. Results are given in Table 4. This adhesive provided rather poor T-peel strengths with EPDM-1, PVC-1, modified PVC-1 and moderately low strengths with CPE-1, Specimens 32, 34, 35 and 36, respectively. Considerably higher T-peel strengths were obtained using the contact cement with CSPE-3 and PIB-1, Specimens 33 and 37, respectively. Although membrane material failure did not occur in either case, the solvents in the contact cement appeared to enhance the seam bonding with these two materials.

The next procedure investigated the use of seaming tapes as a repair or patching procedure. These are of particular interest because of potential environmental problems associated with many of the seam adhesives.[13] Table 5 presents T-peel test results for EPDM-1 and EPDM-3 seam tapes. These tapes provided moderate to relatively good T-peel strengths for the EPDM membranes, Specimens 38-42, and the CSPE membranes, Specimens 43-45, respectively, and the PVC, CPE and PIB membranes, Specimens 46, 48 and 49, respectively. A comparison of EPDM Specimens 40 versus 39, of CSPE Specimens 44 and 45 versus 43, illustrate the value of priming the seam with the respective seam primer over merely washing the seams with solvent and no seam primer. There appears to be little difference between the effectiveness of the two different seam tapes investigated.

The seam tape did not perform well with the modified

PVC, Specimen 47, which exhibited a rather low T-peel strength even when using the seam primer. It is possible that a different washing solvent or other type of primer might enhance the T-peel results with the modified PVC, thus making the seam tape useful with these materials also.

The fact that the seam tape method worked well with the different generic types of membranes suggests that the seam tape procedure might be acceptable using one generic type of membrane, such as EPDM, to patch other generic types of membranes.

The final procedure investigated as a "universal patching procedure" in this initial phase was acrylic elastomer coating with embedded polyester/fiberglass scrim. This method was of interest because it had a strong potential as a repair procedure using readily available materials that are environmentally safe which is a major consideration. Results, which are given in Table 6, show very low T-peel strengths for this method of patching with the acrylic roof coatings and the four EPDM and one CSPE membranes. Very little difference was observed in results when using the two different acrylics or the two different cleaning procedures. Because of the low results, this method was not pursued with other types of membranes during this phase of the investigation.

SUMMARY AND CONCLUSIONS

The objective of this research was to investigate various procedures that could be developed into one or two 'universal repair procedures' for patching or repairing single-ply roofing systems at naval facilities. In pursuing the research, different seaming procedures and different approaches to patching were investigated. A review of the T-peel test data presented in Tables 1 - 6 suggests two or three different procedures either alone or together might serve the desired purpose and merit further research in later phases of the study.

Results of this research suggest that butyl seaming tapes exhibit the necessary characteristics to serve as a 'universal repair procedure' for most of the different generic types of single-ply roofing systems. Further investigation of different seaming tapes, cleaning and priming procedures appears to be warranted.

Another alternative is: (1) use of one of the EPDM adhesives (Table 2) for repairing EPDM, CSPE and PIB with EPDM membrane; and, (2) heat welding PVC, modified PVC and CPE using PVC membrane. Both of these procedures should be investigated further.

Because this study was the preliminary phase, many questions remain and a number of parameters must be determined before final procedures are established. One of the more important factors involves determining the long-term compatibility of the different membranes/adhesive/seaming materials in additional phases of the work. Further investigations should also include determining the repairability of "aged" membrane materials, and minimizing or eliminating unacceptable solvents from adhesives, cleaners and primers. It is realized that the repairability of "aged" membranes may vary greatly from new materials especially where uncured elastomer membranes are involved. All of these factors must be considered in light of current and potential future environmental requirements.

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Specimen	Membrane	Peel Strength in kN/m (lb/in) Avg.	Range	STD	COV
1.	EPDM-1[2]	0.51 (2.93)	0.40-0.57 (2.29-3.28)	0.07 (0.42)	14
2.	EPDM-1[2,4]	0.62 (3.54)	0.55-0.67 (3.13-3.81)	0.05 (0.28)	8
3.	EPDM-1[2,5]	0.70 (3.99)	0.49-0.81 (2.80-4.65)	0.13 (0.72)	18
4.	EPDM-1[3]	1.04 (5.94)	0.75-1.34 (4.28-7.65)	0.20 (1.14)	19
5.	EPDM-1[6]	0.88 (5.02)	0.72-1.05 (4.12-6.02)	0.13 (0.77)	15
6.	EPDM-1[3,7]	0.98 (5.58)	0.41-1.20 (2.36-6.83)	0.32 (1.82)	33
7.	EPDM-2[2]	1.37 (7.84)	0.91-1.59 (5.22-9.06)	0.27 (1.56)	20
8.	EPDM-2[3]	0.61 (3.46)	0.54-0.72 (3.09-4.12)	0.07 (0.39)	11
9.	EPDM-3[2]	0.95 (5.43)	0.68-1.20 (3.90-6.88)	0.19 (1.11)	20
10.	EPDM-3[3]	0.40 (2.30)	0.30-0.58 (1.70-3.31)	0.11 (0.62)	27
11.	EPDM-4[3]	0.78 (4.43)	0.67-0.86 (3.84-4.92)	0.07 (0.42)	9
12.	CSPE-1[2,4]	2.14 (12.2)	1.80-2.82 (10.3-16.1)	0.41 (2.36)	19
13.	CSPE-2[2,8,9]	2.49 (14.2)	1.82-4.15 (10.4-23.7)	0.98 (5.57)	39
14.	PIB-1[2,4,9]	1.03 (5.88)	0.94-1.17 (5.38-6.68)	0.09 (0.50)	9

1. Long open time unless noted otherwise.
2. Cleaning Procedure 1.
3. Cleaning Procedure 2.
4. Short open time.
5. Adhesive stirred for additional period of time.
6. Scrubbed with steel wool soap pad and water only.
7. Scrubbed with GI brush, soap and water followed by Cleaning Procedure 2. Seam pressed with a roller.
8. Seam area cleaned with xylene.
9. Material failed in all cases (cohesive failure of sheet, rather than adhesive or cohesive failure of adhesive).

Table 1 Peel strength of seam specimens using manufacturer's recommended adhesive.[1]

Specimen	Membrane	Peel Strength in kN/m (lb/in) Avg.	Range	STD	COV
15.	EPDM-1[3]	1.04 (5.94)	0.75-1.34 (4.28-7.65)	0.20 (1.14)	19
16.	CSPE-3	0.19 (1.10)	0.15-0.29 (0.84-1.63)	0.06 (0.32)	29
17.	CSPE-3[4,5]	0.95 (5.44)	0.78-1.10 (4.45-6.26)	0.15 (0.87)	16
18.	CSPE-1	0.41 (2.32)	0.33-0.43 (1.87-2.45)	0.04 (0.25)	11
19.	PVC-2	0.12 (0.68)	0.09-0.15 (0.49-0.88)	0.03 (0.16)	24
20.	PVC-1	0.12 (0.66)	0.08-0.19 (0.46-1.10)	0.05 (0.26)	40
21.	Mod.PVC-1	0.49 (2.77)	0.42-0.56 (2.38-3.22)	0.05 (0.30)	11
22.	CPE-1	0.47 (2.68)	0.42-0.58 (2.40-3.31)	0.06 (0.36)	13
23.	PIB-1[6]	1.20 (6.85)	1.03-1.29 (5.86-7.36)	0.10 (0.59)	9

1. Cleaning Procedure 1 unless noted otherwise.
2. Long open time.
3. Cleaning Procedure 2.
4. Adhered seam cured for 11 days before testing.
5. Membrane cleaned with xylene rather than hexane.
6. Membrane failed in all cases.

Table 2 Peel strength of seam specimens using EPDM-1 adhesive.[1,2]

Specimen	Membrane	Avg.	Peel Strength in kN/m (lb/in) Range	STD	COV
24.	EPDM-1[2]	0.098 (0.56)	0.082-0.112 (0.47-0.64)	0.011 (0.059)	11
25.	EPDM-1[2,3]	0.212 (1.21)	0.193-0.240 (1.10-1.37)	0.019 (0.11)	9
26.	EPDM-2[2]	0.273 (1.56)	0.186-0.436 (1.06-2.49)	0.095 (0.54)	35
27.	EPDM-3[2]	0.105 (0.60)	0.088-0.124 (0.50-0.71)	0.014 (0.076)	13
28.	EPDM-4[2]	0.110 (0.63)	0.095-0.128 (0.54-0.73)	0.014 (0.081)	13
29.	CSPE-1[2]	0.686 (3.92)	0.641-0.744 (3.66-4.25)	0.042 (0.24)	6
30.	CSPE-2[4,5]	2.487 (14.2)	1.821-4.150 (10.4-23.7)	0.975 (5.57)	39
31.	CSPE-3[2]	0.716 (4.09)	0.602-0.814 (3.44-4.65)	0.095 (0.54)	13

1. Cleaning Procedure 2 used unless noted otherwise.
2. Short open time.
3. New can of adhesive.
4. Seams cleaned with xylene using cleaning Procedure 1.
5. New two component adhesive material used (CSPE-2 adhesive). Membrane material failed in all cases.

Table 3 Peel strength of seam specimens using special two component adhesive.[1,2]

Specimen	Membrane	Avg.	Peel Strength in kN/m (lb/in) Range	STD	COV
32.	EPDM-1	0.29 (1.67)	0.20-0.43 (1.14-2.43)	0.09 (0.50)	30
33.	CSPE-3	0.84 (4.80)	0.64-1.13 (3.66-6.46)	0.19 (1.06)	22
34.	PVC-1	0.19 (1.08)	0.18-0.21 (1.01-1.19)	0.01 (0.07)	6
35.	Mod.PVC-1	0.15 (0.85)	0.12-0.19 (0.71-1.06)	0.03 (0.16)	19
36.	CPE-1	0.38 (2.16)	0.28-0.44 (1.59-2.51)	0.06 (0.36)	17
37.	PIB-1	1.30 (7.45)	1.26-1.33 (7.19-7.61)	0.03 (0.17)	2

1. Cleaning Procedure 2.
2. Long open time.
3. Seams pressed with a roller.

Table 4 Peel strength of seam specimens using conventional contact cement adhesive.[1,2,3]

Specimen	Membrane	Avg.	Peel Strength in kN/m (lb/in) Range	STD	COV
38.	EPDM-1[3,5]	0.47 (2.71)	0.40-0.56 (2.29-3.22)	0.07 (0.40)	15
39.	EPDM-1[2,3,5,7]	0.84 (4.82)	0.78-0.95 (4.48-5.45)	0.07 (0.38)	8
40.	EPDM-1[2,3,6]	1.15 (6.59)	1.08-1.23 (6.19-7.01)	0.05 (0.29)	4
41.	EPDM-2[3,5]	0.77 (4.42)	0.73-0.83 (4.19-4.72)	0.04 (0.24)	5
42.	EPDM-3[2,4,6]	0.60 (3.41)	0.50-0.83 (2.84-4.74)	0.13 (0.77)	23
43.	CSPE-3[3,5,7]	0.37 (2.11)	0.30-0.42 (1.72-2.39)	0.05 (0.28)	14
44.	CSPE-3[2,4,6]	0.81 (4.60)	0.61-1.02 (3.48-5.84)	0.15 (0.86)	19
45.	CSPE-3[2,4,6]	0.70 (4.01)	0.53-0.86 (3.02-4.89)	0.15 (0.83)	21
46.	PVC-1[2,4,6]	0.58 (3.34)	0.49-0.64 (2.82-3.66)	0.06 (0.35)	10
47.	Mod.PVC-1[2,4,6]	0.27 (1.56)	0.20-0.38 (1.12-2.16)	0.07 (0.40)	26
48.	CPE-1[2,4,6]	0.86 (4.90)	0.72-0.95 (4.14-5.42)	0.09 (0.54)	11
49.	PIB-1[2,4,6]	0.70 (3.97)	0.65-0.72 (3.70-4.10)	0.03 (0.16)	4

1. Cleaning Procedure 2, short open time.
2. Seams pressed with a roller.
3. EPDM-1 seam tape.
4. EPDM-3 seam tape.
5. No seam tape primer applied to membrane seam area.
6. Seam tape primer applied to membrane seam area before tape application.
7. Membrane cleaned with xylene using cleaning Procedure 1.

Table 5 Peel strength of seam specimens using seam tapes for EPDM 1 and 3.[1,2]

Specimen	Membrane	Coat.	Peel Strength in kN/m (lb/in) Avg.	Range	STD	COV
50.	EPDM-1[1]	1	0.046 (0.26)	0.039-0.051 (0.22-0.29)	0.005 (0.027)	10
51.	EPDM-1[1]	2	0.042 (0.24)	0.039-0.051 (0.22-0.29)	0.004 (0.018)	8
52.	EPDM-1[2]	1	0.046 (0.26)	0.039-0.058 (0.22-0.33)	0.007 (0.041)	16
53.	EPDM-1[2]	2	0.065 (0.37)	0.039-0.119 (0.22-0.68)	0.032 (0.18)	50
54.	EPDM-2[2]	1	0.161 (0.92)	0.109-0.243 (0.62-1.39)	0.054 (0.31)	34
55.	EPDM-2[2]	2	0.089 (0.51)	0.077-0.105 (0.44-0.60)	0.011 (0.060)	12
56.	EPDM-3[2]	1	0.079 (0.45)	0.065-0.089 (0.37-0.51)	0.011 (0.057)	13
57.	EPDM-3[2]	2	0.060 (0.34)	0.051-0.070 (0.29-0.40)	0.011 (0.055)	16
58.	EPDM-4[2]	1	0.074 (0.42)	0.061-0.077 (0.35-0.44)	0.007 (0.038)	9
59.	EPDM-4[2]	2	0.074 (0.42)	0.054-0.086 (0.31-0.49)	0.014 (0.079)	19
60.	CSPE-1[1]	1	0.067 (0.38)	0.058-0.089 (0.33-0.51)	0.012 (0.071)	18
61.	CSPE-1[1]	2	0.042 (0.24)	0.035-0.046 (0.20-0.26)	0.004 (0.024)	10

1. Cleaning Procedure 1.
2. Cleaning Procedure 2.

Table 6 Peel strength of patching system using acrylic elastomer coatings with embedded polyester/glass scrim.