All Thermoplastic Rolls Are Not Equal

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THE MANUFACTURERS OF wide-width single-ply rolls make marketing claims that the wide-width products have application advantages because, compared with systems using narrower rolls, there are fewer seams and installation is quicker. While this claim may be accurate when wide-width rolls are used in fully adhered and plate-bonded systems, it is not necessarily accurate for side-lap mechanically attached applications. The installation process for wider and heavier rolls can take longer and pose several workforce challenges for the installers.

Wide-width rolls have entered the market in recent years, providing advantages for both fully adhered and plate-bonded systems where the wider sheet has reduced the number of seams and T-joints. While the advantages are clear for these types of systems, the advantage does not necessarily extend to lap-attached mechanically fastened systems. Fastener and stress plate technology has increased the uplift performance of mechanically attached assemblies; however, systems installed over 18 to 22 ga (1.2 to 0.7 mm) 33 kip/in.^{2} (228 MN/m^2) decking have limitations as the sheets get wider.

To investigate claims that it is more cost effective to use wide-width rolls in mechanically attached systems, we analyzed side-lap attachment spacing and seam welding lengths comparing the use of wide-width rolls versus more traditional narrower rolls. This article presents our findings, which demonstrate installation of traditional roll width in a mechanically attached format is faster than the wider-width rolls. The key factor in application rate is the spacing of lap attachment. The reduction in seam welding using wide-width rolls is not sufficient to offset the increase in the fastening pattern.

Roll widths have increased from the historically common (or "traditional") widths of 72 and 81 in. (1,829 and 2,057 mm) to widths of 8 (96 in.), 10 (120 in.), 12 (144 in.), and 16 ft (192 in.) (2,438, 3,048, 3,657, and 4,876 mm). Sales and marketing literature for wide-width rolls suggest these products accelerate installation speed; however, that assertion does not account for the additional labor factors that add to installation time, particularly the process of mechanical attachment and maneuverability of larger and heavier rolls. While wider rolls offer advantages when applied in an adhered or plate-bonded system, wide-width rolls require more fasteners to meet the same wind uplift resistance and have greater handling issues when compared to traditional roll sizes; therefore, labor costs for mechanically attached systems are only lower when traditional-width rolls are used. Simple math does not support the premise that wide-roll mechanically attached systems are more cost effective.

There are three primary variables that affect the speed of installation of a mechanically attached roof cover: the number of fasteners installed into a side lap; the maneuverability of the rolls, and the total lineal footage of welds.

Rooftop productivity for specific types of roof systems was evaluated through time trials by Trinity | ERD that was initially commissioned by a membrane manufacturer to compare the labor required to install a variety of roof systems, including, but not limited to, modified bitumen

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Input Parameters - 8 Foot Wide Roll				Input Parameters - 10 Foot Wide Roll			
Roof Length	L	100	Ft	Roof Length	L	100	Ft
Roof Width	W	100	Ft	Roof Width	W	100	Ft
Total Area		10,000	SF	Total Area		10,000	SF
Roll Length	L_r	100	Ft	Roll Length	L_r	100	Ft
Roll Width	W_r	8	Ft	Roll Width	W_r	10	Ft

Roll Calculations			Roll Calculations		
Zone 1			**Zone 1**		
Effective area/roll	756	SF	Effective area/roll	955	SF
Minimum # of Rolls	8	Rolls	Minimum # of Rolls	7	Rolls
Rolls in Y	1	Rolls	Rolls in Y	1	Rolls
Rolls in X	11	Rolls	Rolls in X	9	Rolls
Weld Calculations			**Weld Calculations**		
Perimeter	304	LF	Perimeter	320	LF
Side laps	760	LF	Side laps	640	LF
End laps	0	LF	End laps	0	LF
Total Length	1,064	LF	Total Length	960	LF
Total Weld Time	1.8	Hours	Total Weld Time	1.6	Hours
Fastener Calculations			**Fastener Calculations**		
Fastener Spacing	0.5	LF/fastener	Fastener Spacing	0.5	LF/fastener
Total Fasteners	1,672	Fasteners	Total Fasteners	1,440	Fasteners
SF/Fastener	3.5	SF/fastener	SF/Fastener	4.4	SF/fastener
Total Fastener Time	12.54	hours	Total Fastener Time	10.8	hours
Total Time Zone 1	14.4	hours	Total Time Zone 1	12.4	hours
Zone 2			**Zone 2**		
Effective area/roll	714	SF	Effective area/roll	914	SF
Minimum # of rolls	7	Rolls	Minimum # of rolls	5	Rolls
Perimeter length/Roll length	5	Rolls	Perimeter length/Roll length	5	Rolls
# of half width rolls across	3	Rolls	# of half width rolls across	3	Rolls
Width of Zone 2	12	LF	Width of Zone 2	10	LF
Weld Calculations			**Weld Calculations**		
Perimeter	704	LF	Perimeter	720	LF
Side laps	800	LF	Side laps	800	LF
End laps	108	LF	End laps	135	LF
Total Length	1,612	LF	Total Length	1,655	LF
Total Weld Time	2.77	Hours	Total Weld Time	2.84	Hours
Fastener Calculations			**Fastener Calculations**		
Fastener Spacing	0.5	LF/Fastener	Fastener Spacing	0.5	LF/Fastener
Total Fasteners	2,400	Fasteners	Total Fasteners	2,400	Fasteners
SF/Fastener	1.7	SF/Fastener	SF/Fastener	1.7	SF/Fastener
Total Fastener Time	18	Hours	Total Fastener Time	18	Hours
Total Time Zone 2	20.8	Hours	Total Time Zone 2	20.8	Hours
Total Weld Time	4.6	Hours	Total Weld Time	4.5	Hours
Total Fastener Time	30.5	Hours	Total Fastener Time	28.8	Hours
Total	**35.1**	**Hours**	**Total**	**33.3**	**Hours**

Figure 1. *Time calculations performed by the calculator for a 100 × 100 ft (30 × 30 m) roof using 72 and 81 in. wide (1,829 and 2,057 mm wide) rolls.*

mechanically attached along seams, polyvinyl chloride (PVC) and thermoplastic olefin (TPO) membranes. The time trials included other systems, such as self-adhered and two-ply fully adhered modified bitumen systems. Some of the data generated from the study can be used to compare worker hours required to install a range of roll widths, specifically focusing on installation of fasteners and seam welding. Using the data collected during the time trials, we have created a calculator that can be used to evaluate all lap-attached assemblies. Screenshots of the calculator are shown in **Figs. 1** and **3**.

The labor data used in the comparison were generated from observations of 72 PVC and TPO roof installations that were within a specific size, height, and configuration range. The membrane manufacturer established size and height criteria to minimize variables in the database. The assemblies were in every region of the US over steel, wood, and concrete decks. The data used in the following example, shown below, assumes a fastener length of 4 in. (100 mm) and a 60 mil thick (1.5 mm) PVC or TPO roof cover.

Welding speeds were calculated taking an average installation time of two hours in the morning and two hours in the afternoon; the installation tasks included moving the welder to position, cleaning the welding nozzle, refilling the generator with fuel, and seam checking.

Input Parameters - 72 inch Wide Roll				Input Parameters - 81 inch Wide Roll			
Roof Length	L	100	Ft	Roof Length	L	100	Ft
Roof Width	W	100	Ft	Roof Width	W	100	Ft
Total Area		10,000	SF	Total Area		10,000	SF
Roll Length	L_r	100	Ft	Roll Length	L_r	100	Ft
Roll Width	W_r	6	Ft	Roll Width	W_r	6.75	Ft

Roll Calculations			Roll Calculations		
Zone 1			**Zone 1**		
Effective area/roll	556	SF	Effective area/roll	631	SF
Minimum # of Rolls	11	Rolls	Minimum # of Rolls	11	Rolls
Rolls in Y	1	Rolls	Rolls in Y	1	Rolls
Rolls in X	14	Rolls	Rolls in X	13	Rolls
Weld Calculations			**Weld Calculations**		
Perimeter	304	LF	Perimeter	319	LF
Side laps	988	LF	Side laps	957	LF
End laps	0	LF	End laps	0	LF
Total Length	1,292	LF	Total Length	1,276	LF
Total Weld Time	2.2	Hours	Total Weld Time	2.2	Hours
Fastener Calculations			**Fastener Calculations**		
Fastener Spacing	1	LF/fastener	Fastener Spacing	1	LF/fastener
Total Fasteners	1,064	Fasteners	Total Fasteners	1,037	Fasteners
SF/Fastener	5.4	SF/fastener	SF/Fastener	6.1	SF/fastener
Total Fastener Time	7.98	hours	Total Fastener Time	7.775625	hours
Total Time Zone 1	10.2	hours	Total Time Zone 1	10.0	hours
Zone 2			**Zone 2**		
Effective area/roll	515	SF	Effective area/roll	590	SF
Minimum # of rolls	10	Rolls	Minimum # of rolls	7	Rolls
Perimeter length/Roll length	5	Rolls	Perimeter length/Roll length	5	Rolls
# of half width rolls across	4	Rolls	# of half width rolls across	4	Rolls
Width of Zone 2	12	LF	Width of Zone 2	10.125	LF
Weld Calculations			**Weld Calculations**		
Perimeter	704	LF	Perimeter	719	LF
Side laps	1,200	LF	Side laps	1,200	LF
End laps	108	LF	End laps	122	LF
Total Length	2,012	LF	Total Length	2,041	LF
Total Weld Time	3.46	Hours	Total Weld Time	3.51	Hours
Fastener Calculations			**Fastener Calculations**		
Fastener Spacing	1	LF/Fastener	Fastener Spacing	1	LF/Fastener
Total Fasteners	1,600	Fasteners	Total Fasteners	1,600	Fasteners
SF/Fastener	2.5	SF/Fastener	SF/Fastener	2.5	SF/Fastener
Total Fastener Time	12	Hours	Total Fastener Time	12	Hours
Total Time Zone 2	15.5	Hours	Total Time Zone 2	15.5	Hours
Total Weld Time	5.7	Hours	Total Weld Time	5.7	Hours
Total Fastener Time	20.0	Hours	Total Fastener Time	19.8	Hours
Total	**25.7**	**Hours**	**Total**	**25.5**	**Hours**

Figure 2. *Time calculations performed by the calculator for a 100 × 100 ft (30 × 30 m) roof using 8 and 10 ft wide (2,438 and 3,048 mm wide) rolls.*

An average welding speed of 9.7 ft (3 m) per minute was established using a commonly used automatic welder. A welding crew was defined as 1.5 installers, consisting of a welder and a support person to manage rolls, cords, and probing of the finished seams.

Data collected relating to fastener installation is based on the use of 4 in. (100 mm) fasteners and round stress plates, which were installed by hand with a corded screw gun. The average time per fastener on multiple days on 26 projects was 27 seconds per fastener, which included the time to stage fasteners and plates, set plates on side laps, and reload tool belts with fasteners. Projects using longer fasteners were not included in the time trial data. Longer fasteners had a slightly higher install time; however, the sample size was smaller.

In almost all cases, the number of side-lap fasteners required to successfully test to a 90 psf rating will double when the width of the membrane is 96 in. (2,438 mm) or greater. Both 72 or 81 in. (1,829 or 2,057 mm) wide rolls, require a side lap attachment pattern of 12 in. (305 mm) on center to attain the same 90 psf test rating. The fastener density for a 72 inch wide roll is 5.58 square feet per fastener (60.1

Table 1. Analysis of fastener installation and weld time for a 100 × 100 ft (30 × 30 m) low-slope single-ply roof system

Roll Width	Total Weld Time (hr)	Total Fastener Time (hr)	Total Time (hr)
72 in. (1,829 mm)	5.7	20.0	25.7
81 in. (2,057 mm)	5.7	19.8	25.5
96 in. (2,438 mm)	4.6	30.5	35.1
120 in. (3,048 mm)	4.5	28.8	33.3

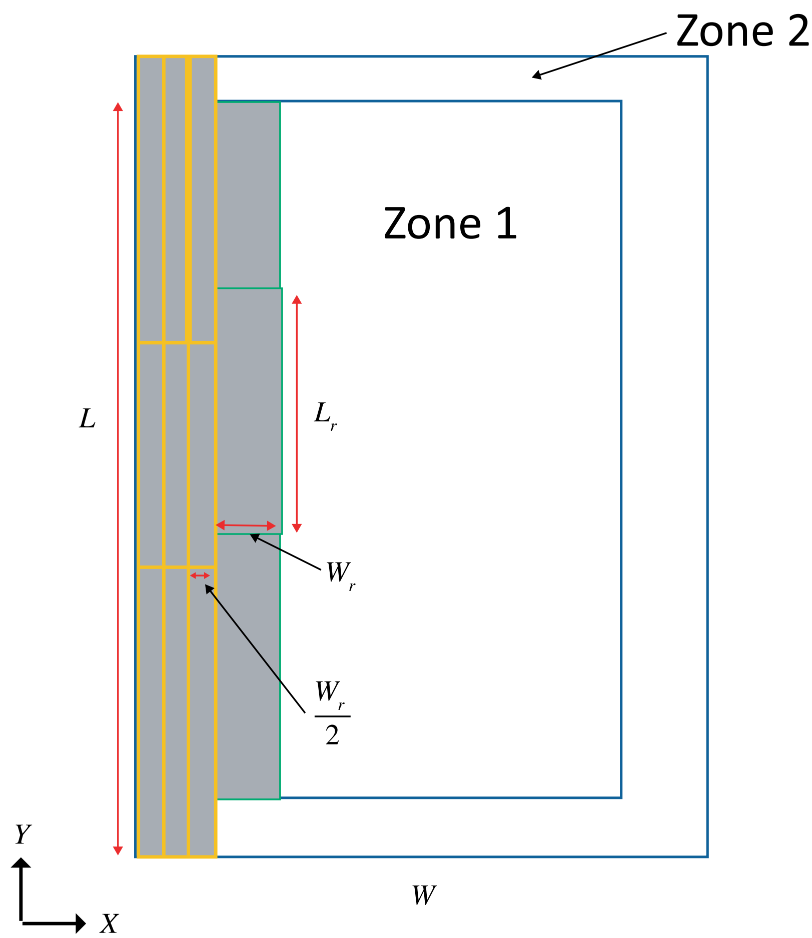

Figure 3. *Roof zone layout with variables defined for use in the calculator.*

Figure 4. *Worker laying out roof roll.*

square meters per fastener) and 6.33 square feet per fastener for an 81 inch roll (68.1 square meters per fastener). In comparison, a 10 ft wide (3,048 mm wide) roll, will require side-lap fastening at 6 in. on center increasing the fastener density to 4.79 square feet per fastener (51.6 square meters per fastener). Of course, fastener density will be increased at perimeters and corners to meet the prescriptive increase for higher calculated uplift pressures. While the time to install fasteners and weld seams will vary from job to job, the fastener density will not change, and the welding speed will be somewhat consistent throughout any project providing temperatures remain within a consistent range. The weld temperature window for each type of membrane will also vary but was not a component of this study.

Any comparison of application of roll widths requires some assumptions about roof size (see the Appendix for the full breakdown). For the purpose of this exemplar a 100 ft × 100 ft (30 × 30 m) low-slope roof is used as a comparison of the different roll widths. Both 72 and 81 in. wide (1,829 and 2,057 mm wide) rolls are compared with both 8 and 10 ft wide (2.4 and 3.0 m wide) rolls. For each type of roll, the total lineal feet of weld and total number of fasteners are calculated, and the average weld speed and fastener times input to determine the weld time and fastener times. The referenced calculator has been developed to input the variables and determine total man hours for these two operations. Hourly pay rates and material costs can be applied to the labor hours to monetize the output. Other variables such as manipulating rolls, cutting around penetrations, and welding of end laps have not been included in the calculation.

Table 1 provides the combined welding and fastener installation time, comparing 72 in. (1,829 mm), 81 in. (2,057 mm), 96 in. (2,438 mm), and 120 in. (3,048 mm) rolls. Note the 120 in. roll requires 1.2 fewer worker hours for weld time; however, that saving is negated by the additional nine worker hours required for fastener installation. Installation of the 81 in. wide roll is 27.5% faster than installation of the 96 in. wide roll and 23.5% faster than installation of the 120 in. wide roll.

Wide-width systems have limitations in terms of wind uplift ratings greater than 90 psf (439 kg/m^2). One TPO manufacturer has published on their website a list of TPO assemblies with FM Global wind uplift approvals, including 96 and 120 in. wide (2,438 and 3,048 mm wide) roll assemblies. For a standard steel deck, there are several 96 in.

Figure 5. *Large-width (16 ft [4.9 m]) rolls being lifted to the roof on a forklift.*

Figure 6. *Additional equipment and more workers are needed to move large rolls.*

Wider rolls increase the contributary area for each fastener if the in-seam pattern remains the same.

wide assemblies that achieve a 90 psf rating by installing fasteners and lap plates at 12 in. (305 mm) on center. These assemblies are clearly faster than a 72 or 81 in. wide (1,829 or 2,057 mm wide) roll system; however, they are non-standard systems with either unusual deck or fastener types. In all cases, the steel deck is either 80 ksi (552 MPa) and/or the screws are no. 21 diameter (0.325 in. [9.53 mm]), which are substantially larger and more expensive than standard roofing fasteners.

Another manufacturer has published a list of assemblies for 120 in. wide (3,048 mm wide) TPO and PVC mechanically attached single-ply membranes. The only assembly that achieves a 90 psf (439 kg/m^2) rating with 12 in. (305 mm) lap fastening uses a non-standard, high-tensile-strength, 80 ksi (552 MPa) steel deck and no. 21 fasteners, which equates to higher material costs. The combination of a high-tensile steel deck and ultra-large fasteners is clearly outside the norm for mechanically attached roofing systems. To add to the material cost the lap plate diameter increases to a 2¾ in. (70 mm) diameter plate.

Achieving an uplift resistance rating with these mechanically attached 120 in. wide (3,048 mm wide) roll systems is problematic, if not impossible, for many roof systems. For many deck types, it is not possible to achieve the 90 psf (439 kg/m^2) rating for 120 in. wide rolls, even with 6 in. (152 mm) fastener spacing. On a standard 22 ga (0.7 mm) thick steel deck, achieving a 90 psf rating is only possible using no. 15 fasteners with 6 in. fastener spacing.

Wider rolls increase the contributary area for each fastener if the in-seam pattern remains the same. The increased load on the fastener may exceed the withdrawal resistance of the fastener in the deck or exceed the rupture value of the plate securing the membrane. By increasing the dimension of the fastener, for example a no. 15 to a no. 21, or increasing the diameter of the plate from 2 to 2¾ in. (50 to 70 mm), the point of attachment may be capable of withstanding a greater load. The alternative is to attach with a more conventional fastener and plate and increase the density from 12 in. on center to 6 in. on center (305 mm on center to 152 mm on center). The module of type A, B, and F decking is 6 in.; therefore, there is no reduction or increase other than a 6 in. (152 mm) change.

The issue of maneuverability of the rolls on site is less scientific. The National Institute for Occupational Safety & Health (NIOSH) and Occupational Safety and Health Administration (OSHA) have established a criterion of a maximum lifting weight limit for a single worker of 51 lb (23 kg). A 45-mil, 72 in. (1.8 m) × 100 ft (30.48 m) TPO roll weighing 102 lb (46.3 kg) can be maneuvered into place by two workers (**Fig. 4**).

Standard-width (72 and 81 in. [1,829 and 2,057 mm]) rolls can be moved using a variety of small conveying devices, including standard hand trucks or wheeled carts, which can be easily maneuvered on a roof deck.

Equipment for moving larger rolls can be costly. Conveyance equipment was developed about 40 years ago to position large ethylene propylene diene terpolymer (EPDM) rolls as large as 20 × 100 ft (6 × 30 m). These larger rolls can weigh as much as 450 lb (204 kg) and may require appropriate power-driven conveying equipment to be moved safely (**Figs. 5** and **6**).

Due to the increased weight, larger rolls should only be moved using mechanical equipment such as hand trucks and forklifts. However, in practice, much of the work done moving these rolls on site is manual, by crew members working in tandem, some who may not have access to the proper equipment or training to handle such heavy loads safely. This manual work can slow down the installation and puts workers at a greater risk of injury such as strains, sprains, and back injuries. The workers in **Fig. 7** are taking a big risk; if any of the workers gets distracted, stumbles, or loses their grip, that worker

Figure 7. *Five workers lifting and transporting a roll weighing over 400 lb (180 kg).*

Figure 8. *Large-width rolls placed on foam. Manufacturers suggest using insulation dunnage to assist in managing rolls.*

or another crew member could be injured. In contrast, standard-width rolls are significantly lighter so they can be lifted and moved more easily, reducing the risk of injury to workers. Additional equipment is unnecessary, and crews can place rolls within NIOSH and OSHA standards.

Even with appropriate equipment, it is sometimes necessary to move large-width rolls by hand. Before laying out the roll, workers must correctly orient the roll, coordinating multiple mechanisms to maneuver the roll(s). Some manufacturers recommend using scrap insulation board under large rolls as a pivot point to rotate the rolls (**Fig. 8**); however, maneuvering these large rolls by hand is challenging without additional rooftop equipment.

The labor costs for the number of workers and equipment to maneuver large-width membrane rolls cannot be calculated with numeric formulas, as can fastener spacing and welding speeds, but it must be a consideration when estimating a project. Factors such as the size and weight of the rolls, the layout of the jobsite, and the availability of rooftop conveyance equipment can all affect the ability of workers to move and position the rolls during installation. In addition, it is important to consider the weight and distribution of concentrated loads when loading the roof. For example, in Fig. 8, the load on the roof is over 800 lb (363 kg).

Another important consideration when installing wider rolls is the number and placement of rooftop penetrations that must be negotiated when unrolling sheet goods. A combination of wide and narrow rolls may make installation easier, with less cutting and patching of the roof cover. Concentrated areas of penetrations, such as skylights or smoke hatches, may be easier to negotiate with 72 and 81 in. wide (1,829 and 2,057 mm wide) rolls.

While every job has its unique conditions, the side-lap fastener spacing and the number of seams that require welding are consistent throughout in the examples shown in the appendices. For single-ply, mechanically attached systems, the analysis shows that, in general, the standard 72 and 81 in. (1,829 and 2,057 mm) wide rolls are faster to install when compared to wider rolls with 6 in. on center side-lap spacing.

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