

Factors Impacting Low-Slope Roofing Costs

A National Labor Study

Executive Summary

Challenges securing and retaining labor have impacted the construction trades for decades, and roofing is no exception. Roofing contractors need to deliver a quality, watertight low-slope roof system profitably with limited labor resources. Effective labor management can be the difference between a successful contractor and a lost business. Roofing contractors have limited resources to improve their ability to estimate labor costs and/or to learn how to better control and reduce labor expense.

Roofing manufacturers attempt to address labor challenges by offering products that require less skill, time and effort. Among other advantages, self-adhered modified bitumen roofing is marketed as a labor-saving solution. Based on this claim, CertainTeed set out to quantify the labor savings self-adhered bituminous roof coverings afford in comparison with other low-slope membranes. The installation of 45 different roofs with six different roof covers in 18 different configurations was observed across the United States. And, while product selection was observed to impact labor time, the efficiency of a roofing crew, or the ability to quickly



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and profitably install a low-slope roof system, cannot be isolated to the type of roof cover they're installing.

Profitability is impacted by three main variables with regards to labor: (1) optimization of a crew's labor efficiency by product and task; (2) accurate/profitable job costing/pricing based on a keen understanding of a crew's labor times by product and task; (3) optimization of project management including crew communication, crew productivity and tool effectiveness.

In order to present an accurate comparison of labor efficiencies across different roof coverings, significant effort was made to minimize key labor-impacting variables on observed projects (i.e. climate was temperate, the crews were equally experienced). Additionally, when key labor-impacting variables were identified, such as tools breaking down or unorganized/unmanaged crews causing delays, the related downtime was recorded separately. Finally, task-level installation data, such as the time required to flash a drain with each roof cover/configuration, has been applied to a single sample project to create an "apples

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to apples” comparison of roof coverings and a clear quantitative analysis.

Based on the roof cover installations observed in this study, it is accurate to conclude that:

- A bituminous roof cover consisting of a mechanically-attached base and a self-adhered cap has a faster installation time than the same base sheet covered with either a torch-applied or hot-mopped cap sheet or a single layer of either TPO or PVC.
- Tools matter. For example, a multi-torch cart or “dragon wagon” can offer significant time savings, under the right conditions, on the field application of a torch-applied project.
- On bituminous roof covers, self-adhered field application can offer labor savings, even if the flashing and penetration details are completed with a torch or mop.
- Flashing details account for a larger percentage of labor on single-ply projects in comparison to multi-layer bituminous projects; this was predominantly observed with installation of base flashings and curbs.
- Bituminous, multi-layer coverings can be installed cost-competitive with single-ply coverings.
- Poorly managed crews, malfunctioning tools and extreme climates will reduce efficiency and increase installation times.

This study is intended to help roofing contractors improve labor efficiencies with their existing labor force in three ways: first, to provide a benchmark analysis of labor for installation of popular roof covers and a reference tool for contractors to compare actual labor values to a current and comprehensive national average. In addition to understanding labor efficiencies by product, this study can help contractors learn to (a) more accurately estimate labor time and (b) optimize labor efficiency across all roof coverings by leveraging the non-product, labor-impacting variables that were observed. Ultimately, roofing contractors must understand all factors that impact their crews. It is imperative for both profit and quality.

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Purpose

Roofing contractor business owners and managers are all too familiar with the challenges around securing and retaining laborers. A commentary on the labor shortage in The Washington Post was unearthed from as early as 1988. In 2015, the National Roofing Contractors Association (NRCA) published, “An industry-wide survey released by the Associated General Contractors of America (AGC) reveals 86 percent of construction firms report difficulty finding qualified workers to fill key positions. Additionally, of the 1,358 survey respondents, 56 percent are having trouble filling roofing worker positions.” In February, 2018, the NRCA published “The skilled labor shortage is so severe that 92 percent of employers say the issue is negatively affecting productivity, employee satisfaction and turnover.” And in May 2018 the NRCA published that some construction firms are now offering signing bonuses in an attempt to combat the labor shortage. A waning labor pool has impacted the building and roofing industry for decades.

The aim of this study is to help roofing contractors improve labor efficiencies with their existing labor force. Initially, CertainTeed’s focus was to provide this support solely through the lens of product selection, with a key objective to document the roof covering that afforded a contractor the lowest labor expense. As a roofing manufacturer, CertainTeed’s efforts to address labor challenges have been focused on designing products that are intended to require less skill and time to install. CertainTeed commissioned an independent study to quantify labor savings associated with self-adhered modified bitumen roof

systems as compared to other modified bitumen application methods and single-ply applications. During the data collection process it was observed that labor efficiency could not be exclusively linked to product selection. Across all roof coverings, it was observed that roofing contractors face two prominent challenges: accurate job costing and effective project management.

When the contractor was willing to share the information, a detailed cost estimate and labor projections was compared to actual time spent. The labor estimate for the first roof observed was under by 15 percent, which was primarily attributed to low assumptions for the installation of accessory components of the roof. Overall, when the opportunity allowed for a comparison of estimates against actual time spent, the comparisons proved revisions for future estimates were warranted. In general, roofing contractors lacked both an internal process to systematically check labor productivity and hone their estimates, as well as an external reference for benchmarking labor goals.

Additionally, it was observed that avoidable labor inefficiencies were tied to poor project management including, but not limited to, tool management and crew management. Due to the nature of competition, very little was observed in the way of sharing best practices, regionally or nationally in this area. As the data was assessed, it became clear that beyond product selection, unique insights associated with job costing and project management could be leveraged to help contractors better control and even reduce labor expense.

Roof Covering Analysis

PLEASE NOTE:

In order to accurately compare labor needs for a multitude of roof coverings that vary significantly, project and crew variables need to be minimized. An overview of the data collection and analysis procedures are included in the following section with a more detailed review provided in Appendix I.

In order to leverage the data into an “apples to apples” comparison of labor needs across roof covers, a sample project has been developed and priced. This allows for an easier assessment of the impact that the variance in time to complete an installation task, such as a drain detail, with one roof covering versus another has on a project. This formatting of the data also aids in understanding the impact that varying project features, such as number of drains, have on labor efficiency. The sample project is not intended to and should not be referenced directly for estimating a project.

When roof coverings are installed in accordance with manufacturer’s published installation recommendations, by trained crews, with proper tools and management, in relatively temperate climates, there are clear differences in labor needs across roof covering types.

- A bituminous roof cover consisting of a mechanically-attached base and a self-adhered cap is faster to install than the same base sheet covered with either a torched or hot-mopped cap sheet or a single layer of either TPO or PVC.
- Flashing details account for a significant percentage of project labor; this was predominantly observed on base flashings and equipment curbs. When installing

- bituminous roof covers, detailing with self-adhered components can offer labor savings, even if the field application is completed with a torch or mop.
- Flashing details account for a larger percentage of labor on single-ply projects than multi-layer bituminous projects

Labor Comparison - Sample Project

The following project parameters create the sample project which was estimated using the collected task-level data:

- 500 squares (50,000 square feet)
- 900 lineal feet of base flashing
- 10 pre-molded pipes
- 6 drains
- 10, 4’x8’ curbs
- 12 field-flashed pipes

An assumed burdened labor rate of \$45 per hour has been applied to calculate labor cost. It does not include general conditions, overhead or profit. It is only labor costs burdened with individual employee associated costs such as medical, workers compensation, etc.

The charts below provide a graphic illustration of the overall difference in labor time (Figure 1) and labor cost (Figure 2) for a variety of roof covering installations. The graphics also illustrate the relative impact of the detail elements of a project to the overall labor needs and labor costs.

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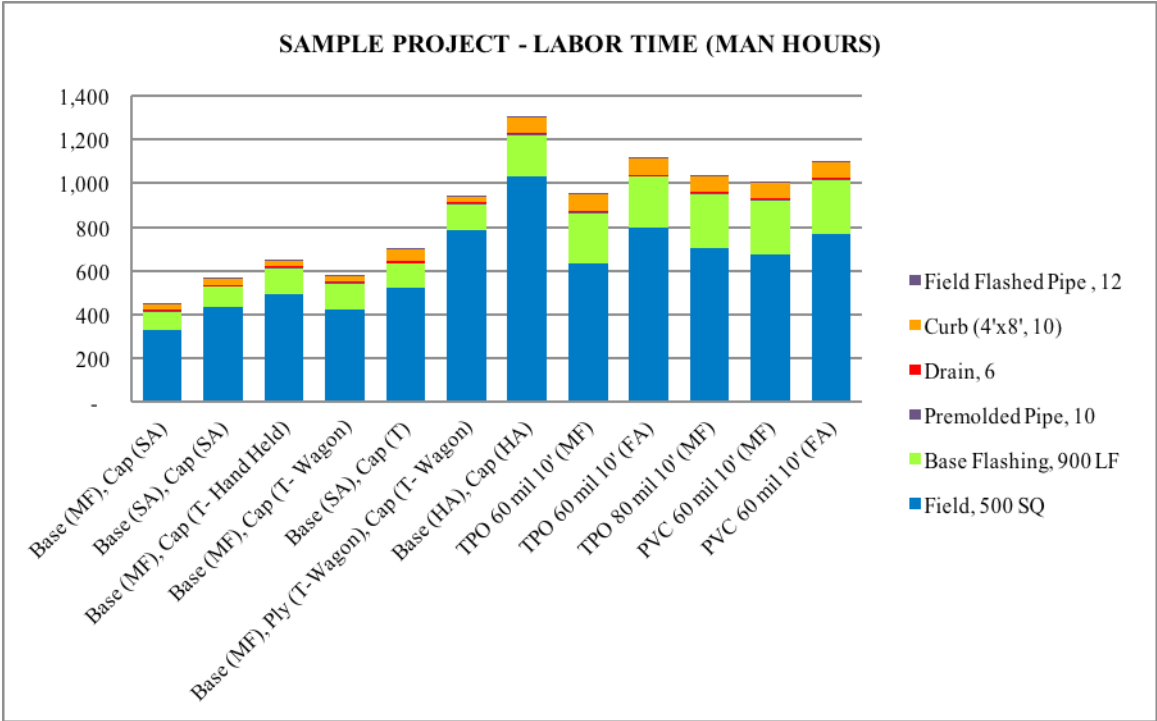


Figure 1 - Man hour comparison using the parameters of sample project outlined above

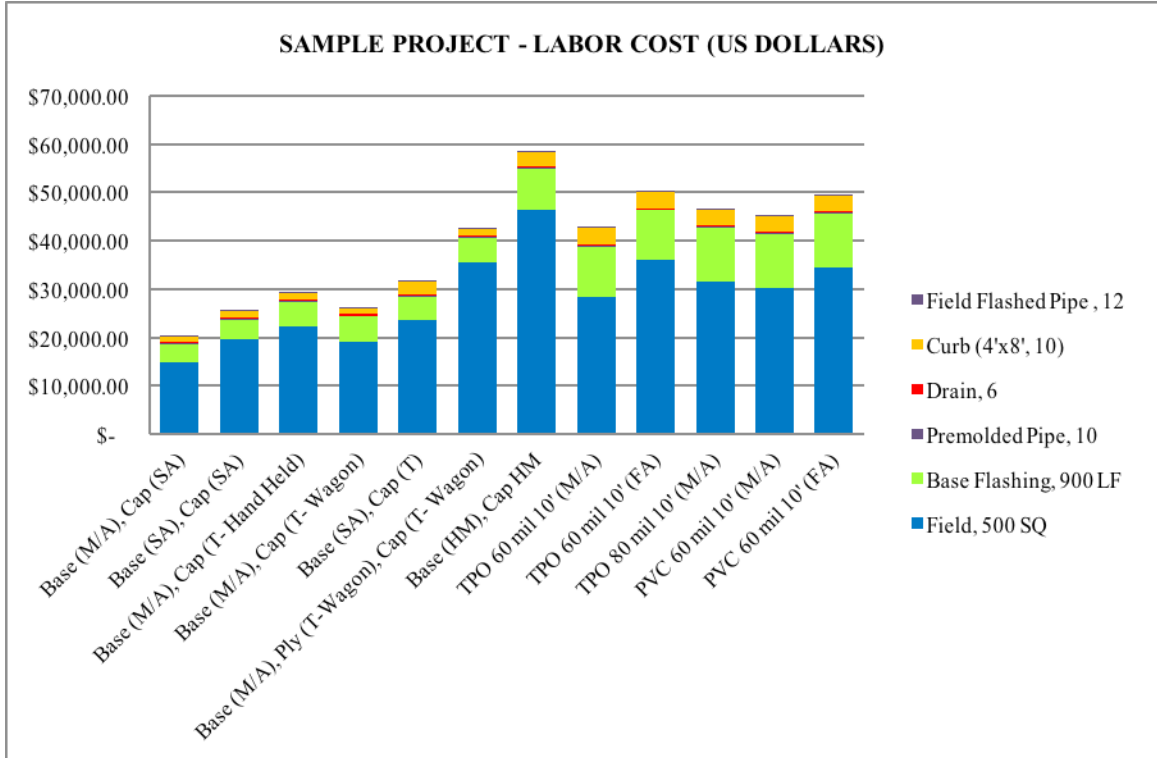


Figure 2 - Labor cost comparison using the parameters of sample project outlined above

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When the data is applied to a sample project, the fastest installed roof covering is a two-ply bituminous system with a mechanically-attached base sheet and a self-adhered cap sheet; the slowest installed system is a bituminous system with both the base sheet and cap sheet installed with hot asphalt. The self-adhered roof cover requires 54.2 man minutes per square; the mopped cover requires 156.5 man minutes per square, a difference of 102.4 man minutes per square (2.89 times) or \$38,390.63 in sample project labor costs. While both the self-adhered and hot-applied systems would be referred to as “two-ply” systems, only the hot-applied system offers two true layers of water protection. A more equitable comparison would be between the two-ply mopped covering and a roof covering with a Mechanically-fastened base, torched interply and torched cap (three total layers, two layers unpenetrated). This covering required 113.5 man minutes; still 28 percent less time than the mopped covering. The mechanically-attached 10’, 60 mil, TPO covering requires 114 man minutes per square. This is 2.11 times the labor of the two-ply bituminous system with a mechanically-attached base sheet and self-adhered cap sheet or a difference of \$22,528.50 in labor costs. The labor associated with the TPO covering is closely comparable to the three-ply bituminous torch-applied covering.

For the purpose of the sample project, a bituminous mechanically-attached base sheet was assumed to be a roll good that complies with ASTM D4601 Type II attached to a steel roof deck through insulation with screws and plates spaced 12” on the lap and two staggered rows of 36” on center in the field. Using this assumption, the man minutes required to install a mechanically-attached bituminous base sheet is

faster than a self-adhered bituminous base sheet; 11.75 man minutes per square versus 15.25 man minutes per square, respectively. It’s important to note that multiple variables will affect the labor time for either of these applications, including, but not limited to:

- Substrate material and thickness
- Ambient temperature
- Fastener type
- Fastening tools
- Crew experience and communication

While the sample data presented indicates that a mechanically-attached base sheet installs more quickly than a self-adhered base sheet, a modification of the variables could reverse the outcome.

The data also indicates several important considerations for flashing details. The labor impact of flashing details varies both by roof covering selection and detail type. Referencing the sample project, overall, 24 percent of the total man hours on the multi-layer bituminous systems are allocated to accessory detailing whereas the same work on the single-ply roof coverings requires 31 percent of the total man hours. It could be concluded, therefore, that projects with a relatively high number of flashing details may warrant stronger consideration for multi-layer bituminous roof coverings as opposed to single-ply coverings to reduce labor expense and total project cost. Such a conclusion, however, would be too broad as the type of flashing detail was observed to have significant bearing on the labor required and the difference in labor across roof coverings. Base flashing and equipment curbs require more labor and have a wider delta for observed time to complete across roof coverings. It was observed to

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take 5.5 man minutes to complete a lineal foot of base flashing with a bituminous mechanically-attached base sheet and a self-adhered cap sheet, 7.75 man minutes per lf for a bituminous base and cap sheet applied in hot asphalt, and 15.25 man minutes per lf for 10', 60 mil mechanically-attached TPO.

Referencing the sample project, the total man hours required for 900 lf of base flashing are:

- Mechanically-attached bituminous base and self-adhered cap: 82.5 man hours
- Mechanically-attached bituminous base and hot-applied cap: 116.25 man hours
- Mechanically-attached 10', 60 mil TPO: 228.75 man hours

The difference between the fastest observed installed base flashing, mechanically-attached bituminous base sheet and self-adhered cap, and the 10', 60 mil, TPO installed base flashing is equal to \$6,581 in sample project labor costs.

Flashing details such as pipes and drains, however, require relatively little time to install regardless of product selection. The average time to complete a drain detail across all observed roof coverings was 64 man minutes. When the task data is applied to the sample project, the difference in drain detail labor needs between the slowest roof covering and the fastest roof covering was a total of 97.5 man minutes, less than \$100 difference in labor cost at a burdened labor rate of \$45/hr.

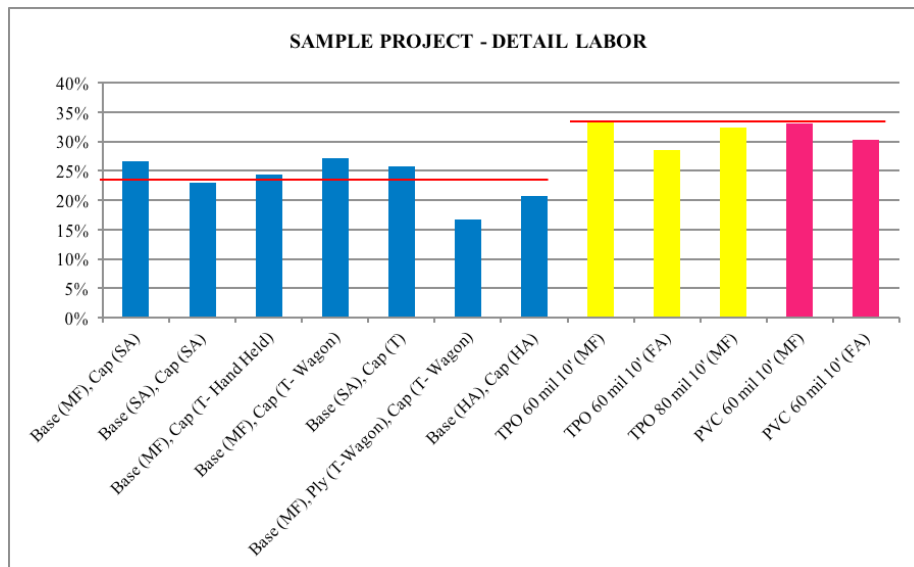


Figure 3 - Percentage of total labor for accessory component installations for each roof covering, using sample project parameters

Both the raw data collected and sample project data illustrate the potential labor savings associated with installation of self-adhered bituminous coverings. Self-adhered bituminous products are relatively new in the commercial low-slope bituminous market when compared to products that are applied by torch or the use of hot or cold asphalt. Encouraging the commercial market to increase acceptance may start with proposing hybrid systems. The majority of roof failures are caused by stress and strain associated with cyclical expansion

and contraction at joints and penetrations. Field membrane typically performs as anticipated, if protected from foot traffic and well maintained. Building owners and specifiers are often asked to provide “value engineering” to cut costs. A hybrid system with a self-adhered roof cover and hot asphalt or torch-applied flashing and penetration details would provide a true “value-engineered” option and a path towards increased comfort for completely self-adhered roof systems.

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While labor and its driving factors are the focus of this study, contractors and end users ultimately make purchasing decisions based on installed costs. In order to provide an installed cost comparison, the observed

labor data has been combined with national average pricing gathered from 22 roofing distribution outlets¹ throughout the United States.

For reference, the following material costs are assumed:

Bituminous Roof Covering Roll Goods Costs (SQFT)

	BUR	APP	SBS (HA/CA)	SBS (SA)
Membrane - Base	\$0.11	\$0.60	\$0.40	\$0.40
Membrane - Cap	n/a	\$0.60	\$0.60	\$0.79

Bituminous Roof Covering Accessory Costs (SQFT)

Propane - Hand-held Torch	\$0.0073
Propane - Multi-Torch Cart	\$0.0089
Hot Asphalt	\$0.07
SBS-Modified Adhesive	\$0.80
Screws/Plates	\$0.11
Asphalt Primer	\$0.08
Pipe Boot (EA)	\$9.65

Single-Ply Roll Goods Costs (SQFT)

	TPO	PVC
Membrane - 45 mil	\$0.53	n/a
Membrane - 50 mil	n/a	\$0.63
Membrane - 60 mil	\$0.70	\$0.78
Membrane - 80 mil	\$0.83	n/a

Single-Ply Covering Accessory Costs

	TPO		PVC	
	60 mil	80 mil	50 mil	60 mil
Screws/Plates (SQFT)	\$0.11			
Adhesive (SQFT)	\$0.43			
Drain (EA)	\$11.50	\$12.07		
Field Flashed Pipe (EA)	\$6.25			
Pipe Boot (EA)	\$9.65			
Corners-4 (EA)	\$18.00			
Curb	\$19.13	\$19.26	\$19.06	\$19.21

Figure 4 - Material cost data

PLEASE NOTE:

Since the above costs are national averages, it must be understood that they may not accurately represent any one region; for the purposes of this study it should be understood that the precise cost is less important than the relative cost when comparing one material to another.

Using the parameters of the sample project, collected material costs and observed labor data, the following installed costs are concluded:

- Some bituminous systems are cost-competitive with single-ply systems.

- The most cost-effective installed roof covering was a bituminous mechanically-attached base sheet and a bituminous torch-applied cap sheet, applied with a multi-torch cart.
- The most expensive installed roof covering was a two-ply non-penetrated (fully-adhered base and cap) bituminous system mop-applied in hot asphalt.
- Single-ply installed costs vary by material and increase with thickness as well as from a mechanically-attached to a fully-adhered covering.

¹ Distribution outlets were a combination of national and regional roofing wholesalers responding to a RFP for 500 squares of products.

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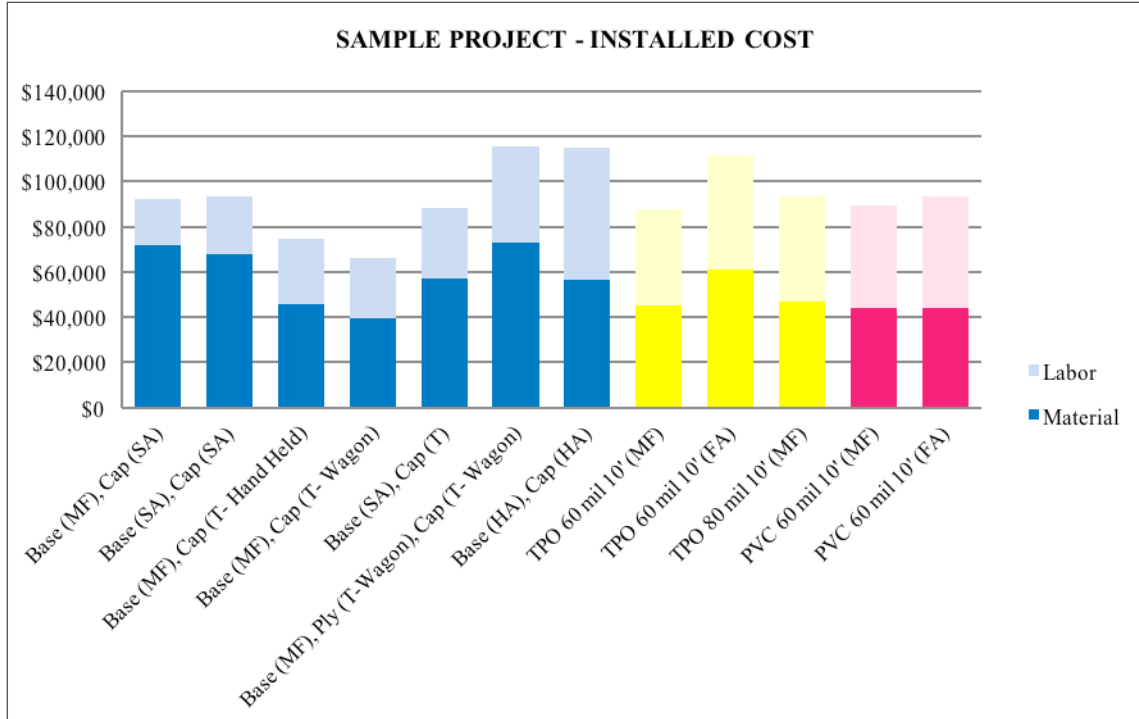


Figure 5 - Graphic representation of labor vs. material costs for sample project parameters

In addition to variations in sample project total installed cost, large variations in the labor cost to material cost ratio are also observed. On average, the installed cost of bituminous assemblies is comprised of 36 percent labor cost whereas the average installed cost of the single-ply roof coverings is comprised of 49 percent labor. The lowest installed cost system, the mechanically-attached base with multi-torch-applied cap is comprised of 40 percent labor. The installed cost for the fastest installed system, the mechanically-attached base with self-adhered cap, is comprised of 22 percent labor. The installed cost for the slowest installed system, the two-ply hot asphalt applied base and cap is comprised of 51 percent labor. The figures are important when considering the impact material cost has on installed costs of roof coverings.

In summary, while under ideal conditions a two-ply bituminous assembly with a mechanically-attached base and a self-adhered cap proved to be the most labor efficient roof covering, and a two-ply bituminous assembly with a mechanically-attached base and a torch-applied cap proved to be the most installed cost effective assembly, in realty roof projects are not always applied under ideal conditions. The roof covering, alone, does not define a project's labor efficiency or time requirement and it is possible that the labor effort described above does not align with an individual contractor's experience in the field with one or more roof coverings. An accurate labor estimate would account for product selection, project parameters and project/crew management with an understanding of how each affects the other. It's important to understand the elements of the installation that were and were not included in the sample data as well as the non-product labor impacting variables that were observed.

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Data Collection & Analysis

CertainTeed Corporation commissioned Trinity ERD, a building envelope consulting firm, well-recognized in the roofing and waterproofing industries, to observe, document and analyze the labor associated with multiple low-slope roof coverings.

Data Collection

The installation of 45 different roofs with six different roof covers in 18 different configurations was observed across the United States. These installations took place

between spring 2011 and autumn 2016. Data was collected from five regions of the country; regions are included in Appendix II.

For the purposes of this study, a roof cover is defined as all materials installed above the insulation and/or cover board, including any anchor sheet layers, adhesives, fuel (propane) or fasteners. No labor was recorded for any installation time aside from the roof cover.

Included in Labor Data	Excluded from Labor Data
<ul style="list-style-type: none"> • Installation of base, ply and cap sheets • Installation of base flashings on low, wood parapet walls 	<ul style="list-style-type: none"> • Tear off • Transportation of materials, roof loading and staging and site clean up • Installation of insulation or cover board
<ul style="list-style-type: none"> • Installation of flashing details such as pipe, drains and equipment curbs • Rooftop working foreman and superintendents • Corrections made to installation (quality control) during the primary installation effort. 	<ul style="list-style-type: none"> • Non-working managerial time • Corrections made to installation (quality control) at any time after the primary installation

Figure 6 – Data included and excluded from data collection

Multiple variables exist on every roof project that can impact labor efficiency, or the time required to complete a task associated with a specific roof cover. Significant effort was extended to minimize these variables and, when unavoidable, extract them from installation time data, though it should be understood that it is impossible to remove 100 percent of labor-impacting factors.

These variables include, but are not limited to:

- Project profile/parameters
- Climate
- Crew size
- Crew management

- Quality control programs
- Tool use/management
- Site specific safety programs

A comprehensive explanation of the data collection procedure can be found in Appendix I.

While additional data was collected, the roof covering comparison included in this document has been limited to the configurations as depicted in Figure 7. Note some assemblies in the comparison were not observed in their entirety; for some assemblies component data was extrapolated from observed roof cover installations to provide the specific assembly data.

	Base	Interply	Cap
BITUMINOUS	1	Mechanically-fastened	Self-adhered
	2	Self-adhered	Self-adhered
	3	Mechanically-fastened	
	4	Mechanically-fastened	
	5	Self-adhered	
	6	Mechanically-fastened	Torch-welded (torch cart)
	7	Hot-mopped	
TPO	8		10', 60 mil, Mechanically- attached
	9		10', 60 mil, Fully-adhered
	10		10' 80 mil, Fully-adhered
PVC	11		10', 60 mil, Mechanically-attached
	12		10', 60 mil, Fully-adhered

Figure 7 – Documented roof covering assemblies

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Data Analysis & Presentation

The installation time data included in this document for each roof cover task represents an average of data collected from as many of the five regions where projects were observed as possible.

In order to leverage the data into an “apples to apples” comparison of labor needs between roof covers, a sample project has been developed and priced. This allows for an easier assessment of the impact that the variance in time to complete an installation task, such as a drain detail, in one roof covering versus another has on a project. The sample project is not intended to and should not be referenced directly for estimating a project.

Data Validation

Field collected data was validated in two ways:

1. RS Means:

RS Means is a nationally recognized database of estimating data published annually by The Gordian Group. The data is regionalized by the application of multipliers applied to specific markets. RS Means provides both labor and material costing within the database. Labor data collected was compared with published 2016 RS Means data for productivity only. Manpower and material costs were not included in the validation review. RS Means provides a general time segment to complete a specified segment of work.

In some cases, the time trials were validated by RS Means; in others RS Means published a larger labor component for the segment of work. No scope of work generated in the time trials posted an average time period greater than that published by RS Means.

It is worth noting that RS Means publishes a significantly higher labor time for self-adhered application than was observed. Trinity ERD has reviewed the variance with RS Means. RS Means communicated that published self-adhered data was extrapolated from flashing observations and not actual field application. RS Means requested permission to publish the self-adhered labor data from this study; CertainTeed has granted that permission.

2. Roofing Estimators:

In specific regions roofing estimators were asked to share data from their estimating programs for time required to carry out specific segments of work. The shared data was compared to actual collected data. Wide variables were identified with some penetration flashings such as drains. Consistently, estimators applied longer periods of time to flash drains for all system types than recorded. This was also consistent with hot stack flashings. Conversely, the installation of termination bars into concrete at the top of a base flashing was consistently underestimated when compared with the time trial data.

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The Impact of Tools & Management

The efficiency of a roofing crew, or the ability to quickly and profitably install a low-slope roof system, cannot be isolated to a specific type of roof cover they're installing. A roofing crew's efficiency is impacted by multiple factors including, but not limited to, climate, project profile, tools, safety requirements,

quality requirements and crew management. Roofing estimators and managers should clearly identify the factors impacting their crews and, where possible, both optimize productivity and adjust estimates to reflect the known measurable impacts.

	Variable Minimization	Estimate Adjustment
Extreme Temperatures/Environment	Crews in the South and Southwest started earlier to avoid late day heat. NOTE this can result in working for periods in low light which can also impact productivity and safety.	Measure the impact that extreme hot and cold working environments have on crew's application tasks and factor any additional time or equipment related to adjustments (lighting, safety) into an estimate.
Staging	Stage materials on projects, with planned and scheduled roof loading to provide easy access for installers.	Account for the additional time needed for material movement, staging and loading if installers are doing this work for themselves.
Crew	<ul style="list-style-type: none"> • Ensure the team is able to effectively communicate • Focus crew members on specialized, repeated tasks when possible • Employ a good rooftop manager • Utilize an in-process quality control program • Manage downtime for breaks, meals and transportation 	<ul style="list-style-type: none"> • Account for downtime if there is a language barrier within the team • Measure variance in labor productivity with and without specialization and appropriately adjust future estimates. • Account for manager cost • Account for QC expense or time (Manager, drop-backs, etc) • Consider all non-productive elements of a workday that will be included in labor costs
Tools	<ul style="list-style-type: none"> • Utilize automation when possible but be sure to have well serviced equipment (including sharp drill bits) and a crew member with the knowledge and tools to adjust or fix the machine as needed • Utilize more sophisticated rooftop power sources when power is required 	<ul style="list-style-type: none"> • Measure the impact that automated equipment has on crew's applicable tasks and factor that time into an estimate-trend this over a few installations to factor in equipment downtime • Measure the reduction in downtime from tripped breakers and apply that to an estimate

Figure 8 - Variable minimization and estimation to account for the impact of tools and management

A more detailed explanation of non-product factors impacting labor are described below:

EXTREME TEMPERATURES/ENVIRONMENTAL

While no one region was generally faster than another, environmental factors associated with a project impact labor and should be factored into estimates. In both high and low temperatures the productivity slowed.

Cold weather created additional work:

- Heating adhesives

- Longer periods for relaxing rolls
- Welding of all types of membrane took longer (APP, SBS, TPO, PVC)
- Heavy and cumbersome cold-weather clothing and gloves increased man hours and resulted in longer and more regular break periods

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Though hot weather had less of an impact than cold, elevated temperatures slowed production as well:

- Fatigue increased man hours
- The need to hydrate results in more break periods.

Fully-adhered membranes were most impacted by weather extremes, slowing installations in the morning hours and creating installation stoppages in the afternoon as temperature increased or decreased.

Additionally, geographical areas that experience regular summertime thunderstorm activity disrupted workflow and altered working hours. It may be assumed that crews working in such locations factor such repetitive downtime into estimates.

Finally, the data collection included three night projects. The install process is slowed when under lights; the area of work is constrained and the entire process is slowed due to darkness. Tools and accessories are more difficult to find. The data was eliminated from the study since the negative variable greatly impacted productivity, and there is a known premium when requiring night work.

CREW VARIABLES

Effective Teamwork

Roof cover installation is optimal when the installing crew works as a coordinated team. Crews that spoke multiple languages with limited understanding of one another reduced the level and frequency in communication and increased installation time.

Specialization

Task productivity, such as man hours required to install a drain flashing, increased when multiple crew members carried out narrowly defined work activities to complete the task as a team, as compared to a single man completing the full breadth of the task alone. The impact of specialized team work was greater on flashing elements than in the roof field.

Another example of specialization efficiency was the application of screws and plates. When hand-

held screw guns were used, laborers that staged and placed screws/plates as one phase of work, and either dropped back to install or were followed by another crew member to install, were more efficient than single individual carrying pouches of screws and plates. Observation indicated the rhythm of the operator was maintained by the focus on a single task.

Roof Staging

Material movement and staging was a critical component in speed at application. Projects that were staged with easy material access for the installers resulted in faster installations. Crews that relied on installers to stage their own materials required fewer personnel on the roof with slower overall install times.

Management

Rooftop supervision and direction played a pivotal role in installation time:

- Effective management of loading the roof; staging materials (projects that were staged with easy material access for the installers resulted in faster installations); prefabrication (such as combining screws and plates); and staging materials to relax prior to installation
- Managing work activities, including breaks

It's important to note that while good management reduced overall labor time, and we subjectively felt that this time savings likely outweighed the cost of said management, management cost would need to be factored into an estimate.

An attempt was made to document the non-productive time primarily to show the number of non-productive minutes in a working day. Initially, a calculation was developed indicating 15.6 percent of an eight-hour working day was, on average, spent on non-productive activities. The variables between projects appeared too great to develop a meaningful percentage that could be used by estimators, but the number can be significant and should be considered for estimates as well as managed in real time.

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Quality Control

A variety of quality control methods were observed across the country. Methods ranged from extensive quality control by both foremen and in-house third-party quality managers to no observed quality process during the application.

A complete lack of in-application quality control reduces upfront labor but undoubtedly requires a crew to return to the roof to correct any issues found post-inspection.

In-application quality control is recommended with the aim of eliminating having to send a crew back to the jobsite for repairs. The techniques for in-application quality control were so varied that a detailed best practice cannot be shared.

If a crew is not properly trained or managed, a self-adhered roof cover could result in elevated labor needs due to corrections. This is true of any roof cover but self-adhered products can be particularly unforgiving.

TOOL VARIABLES

The efficient use of tools and tool accessories measurably impacted the installation times. Examples include, but are not limited to:

1. Multi-Torch Cart (Modified Bitumen Applicator)

The speed and consistency in the installation of APP membrane was markedly increased with the use of this tool. The installation of a bituminous cap membrane with a torch cart was completed in 86 percent of the time required in comparison to a hand-held torch. Using the sample project parameters there is a difference of \$3,093.75 in labor cost. The tool was most effective when the materials were properly staged: a team prepared rolls by opening, relaxing, re-rolling and setting on the cart, propane was staged and the carts were properly adjusted prior to the

start of work. The inclusion of a mechanic or a crew member knowledgeable in the repair and/or adjustment of the unit is also important in maintaining the time advantage. It is important to note the applicator consumed a larger quantity of propane per square.

2. Automated Screw and Plate Installers

Machines that automate screw and plate installation provide a measurable time advantage. Machines do break and jam, resulting in downtime. A knowledgeable mechanic or crew member who has rooftop access to spare parts is an important part in maintaining this time advantage. It's important to note that when the crew relied solely on automatic machines, having no alternate methods of screw and plate installation, there was lengthy downtime as a result of machine malfunction.

3. Poorly Maintained Automatic Welders (Single-Ply TPO/PVC)

All crews used automatic welders for field welding TPO and PVC membranes. Inconsistent power and damaged parts (nozzles and silicone wheels) slowed productivity of the tool and hampered quality of the application.

4. Power

Rooftop power was achieved by either a rooftop generator or tapping into power from the building. Rooftop generators reduced power cord lengths and voltage drop. Some contractors used sophisticated power management systems with built-in ground fault interrupters with a single heavy duty power line tapped into house power while others used a multiplicity of cords plugged into rooftop and internal power receptacles. The latter typically resulted in tripping breakers through the day as circuits were overloaded. In many circumstances this resulted in extended periods of downtime as a crew member left the roof to reset a breaker, leaving other members of the crew without work.

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5. Blowers

Blowers were used on roofs to clean surfaces and to move large sections of membrane on a cushion of air. The tool was effective and increased productivity in both noted applications.

6. Power Tools and Bit Holders

The use of hand-held screw guns was most efficient when properly set up with the correct accessories. Worn or improperly sized power bits dramatically slowed screw installation. Over and under-driven screws also slowed productivity and were a result of improper tool adjustment; this issue primarily impacted applications directly over insulation. In many cases the lack of proper power bits was not corrected even when the problem was systemic.

While the analysis of the data included in this study concluded that the two-ply bituminous system with a mechanically-attached base and multi-torch-applied

cap was the most installed cost-effective assembly, once project profile and project management factors are taken into account, it's not difficult to design a scenario where this result is not accurate. An easy example would be where the multi-torch cart was not properly maintained and the crew did not include a mechanic to address on-roof equipment failures. Labor on such a project would skyrocket if a crew was left standing around while the foreman problem solved.

And let's return to the fastest installed system: the two-ply bituminous system with a mechanically-attached base and self-adhered cap. A number of project profile factors could impede the success of this installation. One example is extreme heat. Self-adhered membranes get increasingly unforgiving with placement as heat increases during working time and increase in drop backs during application, or worse, call backs after application to correct wrinkles can be devastating to labor efficiency.

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Conclusions

CertainTeed originally set out to determine if self-adhered roof coverings delivered on the labor-savings they aspired to provide. This study quantifies and confirms self-adhered coverings can be installed in less time than other bituminous application methods as well as single-ply coverings, including TPO and PVC.

Assessing total installed cost, per sample project parameters, the least expensive roof covering was a bituminous mechanically-attached base and a multi-torch-applied cap. While not as fast to install as a self-adhered cap, torch-applied materials tended to have lower cost than their self-adhered cousins. The self-adhered bituminous coverings were installed cost-competitive with single-ply coverings.

The data indicates that detail application can have a significant impact on project costs and profits. Bituminous self-adhered detail application, in like manner with field application, offers reduced labor over other bituminous applications and single-ply coverings. Increased acceptance of bituminous self-adhered systems may start with proposing hybrid systems with a self-adhered roof cover and hot-applied or torch-applied flashing and penetration details.

Under ideal conditions on a singular sample project, the relative installed cost and labor comparisons above are clear, and product selection indisputably

has an impact on labor efficiencies, but it would be inaccurate to name any one roof covering the fastest or most cost effective for all low-slope roofing projects for all low-slope roofing contractors. Nothing is “one-size-fits-all” in the roofing market. The perceived value in one system may not carry across every roof design, or meet what is needed for the local climate. All aspects of the project must be incorporated into product and roof assembly selection. Further, installation requires a level of expertise with good quality control and quality assurance to ensure long-term performance is as intended. Project parameters and project management apply a high degree of variability to every job. Training, project management and crew management variables can significantly increase or decrease efficiency.

Roofing contractors have the opportunity to enhance profitability through a comprehensive understanding and optimization of their crews’ processes and performance per roof covering as applied to multiple project profiles and conditions. Such a deep and living documentation should be a well-managed process within a roofing contractor’s standard operating procedures. This intelligence directly contributes to a contractor’s ability to produce accurate job costing and pinpoint where improvements in project and crew management are needed, enabling them to extract the most profit from their business.

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Appendix I - Data Collection

It has previously been recognized that many variables exist on every roof project that can impact labor efficiency. While significant effort was extended to minimize these variables and extract them from installation time data, it is impossible to remove 100 percent of labor-impacting factors. The following details how data was collected and documented.

Project Profiles

Installation time collection was limited to projects:

- No greater than 35' in height
- 20-22 gauge, Type 'B' steel decks
- Slopes ranging from 1/8" - 1/2" in 12" of fall
- Internal drains, perimeter gutters or through-wall scuppers
- Roof penetrations consisting of HVAC curbs, pre-molded vent pipes, field-flashed vent pipes, hot stacks; skylight and smoke hatches
- Perimeter flashings at a gravel stop or conventional base flashings

The most common description of projects where data was recorded is a warehouse/office structure with one elevation; an elevation of loading docks with an average height of 24.76 ft. The highest elevation was 35' representing a two story mezzanine attached to a warehouse structure with a main roof area of 22.5' in height.

Projects consisted of a combination of new construction and re-roofing. When the project was a re-roof, the entire existing roof and insulation was removed to the deck.

Roof assemblies varied in insulation types and thicknesses. Types of cover boards, when employed, also varied including gypsum, high density polyisocyanurate, wood fiber and perlite-based products. Crickets were installed at perimeter and corner areas of the roofs; however, no full-tapered systems were a part of the sample set.

Roof penetrations are, in many cases, installed in stages. For example, a flashing membrane may be installed and tacked into place as a first step. A termination bar is installed at a later date and finished with a sealant application to complete the full installation. The data generated reflects all of the steps through final installation of sealant. Installation of vapor retarders, insulation, cover boards and walk pads were excluded due to the variables these could create in the collected data.

Base Sheet Application

When mechanically-attached base sheets were installed the attachment was, in all cases, the attachment of the combined base sheet and underlying substrate insulation and/or cover boards. Screws' lengths ranged from 4" to 7", the majority of which ranged between 5" to 6"; insulation plates ranged from 3" to 4".

Extreme Temperatures

Any additional work components (i.e. warming sheets) were extracted and not included in installation time data, however, tasks that simply took a longer period of time were tabulated unaltered. Cold-weather installations impacted the averages in regions where cold-weather roofing is commonplace. The study averaged the cold-weather applications with the sample population.

Crew Size/Management

Crew size varied from five to 17 excluding support laborers. Some crews had working foremen and others had superintendents that did not actively participate in installation. Typically, larger crews employed non-working foremen who directed the activities of the crew and the support personnel. Working foremen took on a dual role of both roof system installation and overall crew management.

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Where working foremen were part-time workers, the actual work time was separated from the management or supervisory time to best capture application data. If the work was purely supervisory the time was excluded.

An attempt was made to quantify supervisory time by roof system type and average the supervision required for each project. Insufficient reliable data was collected; therefore, the category was removed from this study. The data that was developed indicates field management skills can play a measurable role in the efficiency of the field operation.

Quality Control Labor

Due to the high variability of the process and related manpower, the quality control tasks were excluded from system-specific labor data wherever possible. However, where quality control was in 'real time', repairs became a component of the installation and were included in the data. Where repairs were post-installation, the time was not captured unless the install crew 'dropped back' to repair during the initial installation period. The lack of a consistent quality control program created an unavoidable discrepancy in the time trial data.

Breaks, Meals and Transportation

Time for breaks, meals and transportation were not counted in the installation time. While they are a part of the overall cost of the installation, the time was reduced to actual work periods.

As with meals and breaks, transportation proved to be too variable to develop any meaningful data. Some crews were paid based on time on job site and others portal to portal from the contractor's yard.

Tools

Many crews also combined conventional screw guns with automatic tools. There is no separation of automatic screw and plate installation from

conventional methods of installation. Where crews pre-assembled screws and plates on site, this labor element was captured and included.

Labor Costs

A fully burdened labor rate, including hourly wages and benefits, of \$45/hr was utilized for the installed cost comparison. This rate was determined by averaging the published labor rates from the five regions of the United States that were included in this study.

Material Costs

Material pricing to contractors was obtained by contacting 22 roofing distribution outlets across the country. The data presented is an average of these prices.

Electricity costs (generator or house power) were not taken into the installed cost matrix but should be considered by estimators for true project cost.

A complete detail of material costs included in this document is listed in Appendix III.

AVERAGING DATA

Data collected within each region was averaged to generate the time data presented in this document. When data exceeded an 11 percent variance from one region to another, the data was reevaluated to identify anomalies that may have created such wide variances. As an example, drain installs in the Northeast exceeded drain install time trial data when compared to the Northwest and Southwest. A review of the data identified two Southeast region projects with complicated drain sumps and drain modifications. Closer review of data revealed the use of PVC-coated retrofit drains on a west coast project that was substantially more labor intensive to install than more conventional drains. The data was not modified.

