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Technology Impact on the Means and Methods of Wall and Ceiling Construction

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TheFoundation
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Technology Impact on the Means and Methods of Wall and Ceiling Construction

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PREFACE

Foundation of the Wall and Ceiling Industry

In the late 1970s, there was a clear recognition among industry leaders for the need to unite and expand the educational and research activities available to contractors, manufacturers, distributors and the public. At the time, there were many issues facing the industry—from a national energy crisis, to injuries in the workplace, to unsafe buildings occupied by the public.

In response to these issues, the Foundation of the Wall and Ceiling Industry was formed in 1977. As an IRS designated non-profit 501(c)(3) corporation, the Foundation pursues educational and research activities benefiting the industry and the public at-large.

The Foundation's mission is to be an active, unbiased source of information and education to support the wall and ceiling industry.

To fulfill this mission, the Foundation owns and maintains the largest independent library serving the wall and ceiling industry, provides research support to industry inquiries and publishes research papers. In addition, the Foundation provides financial assistance through its AWCI CARES program to AWCI member company employees experiencing hardship.

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TABLE OF CONTENTS

CONTENTS

INTRODUCTION

The need for wall and ceiling contractors to work more productively and safely in today's labor-constrained construction environment is driving investment in project management software, tracking and tagging systems and prefabrication machinery at wall and ceiling firms.

"The big drivers for me are productivity, quality and safety," says Stephen Eckstrom, president, California Drywall Company. "I'm going to adopt more technology if these [drivers] improve."

Technology Investment Is Increasing

While many in the commercial construction industry have been slow to adapt to new technologies, according to various sources, technology investment is increasingly being seen as important.

"[Technology] will ensure that your company is positioned to offer new levels of service that may set you apart from competitors," says Nancy Brinkerhoff, president and CEO of Ironwood Commercial Builders in Northern California and 2019–2020 president of AWCI.

"Companies not on board the automation revolution will be left behind," says S.S. Saucerman in the AWCI's Construction Dimensions article, "The Weakest Link? Us."

Here are three examples of technology investment being made by AWCI member contractors:

- South Valley Drywall in Colorado has automated much of its prefabrication operations. It has engineered its own robotic machines that fasten sheathing to prefabricated metal panels, replacing six fabricators with one machine operator. The company uses 3D printing technology to apply finishes to prefabricated panels. It also buys cold-formed steel coil and roll-forms studs and joists.

- California Drywall in California has for the past seven years invested heavily in computer numerical controlled (CNC) laser and plasma cutting machines and automated cold-formed steel roll-forming machines to drive the rapid assembly of building components. It has invested in building information modeling (BIM) technologies and digital documentation. It has also participated in a virtual reality project with the Wall And Ceiling Alliance.

- T.J. Wies Contracting in Missouri uses a PDF annotator to digitize documents, create reports and notify team members—in real time—when information is available. The reports include daily potential conflicts, daily percent complete and other production performance indicators. A company official says the firm is planning to upgrade from two-way digital documentation management to a more robust enterprise resource planning (ERP) system.

How Is Technology Defined?

Technology is "the science or study of the practical or industrial arts," says Webster's New World College Dictionary. This definition[1] suits the objective of this paper, which is to discuss "practical" applications that affect the wall and ceiling industry's workflows. Technology includes software, tools, collaboration methods, ways to gather and analyze data and more.[2]

What Is Meant by Means and Methods of Construction?

The means and methods of construction is a central principle of construction contracts in which the contractor controls the processes and materials used to build structures falling within his or her scope of work. Often, contractors must provide their own incidental design input, value engineering or minor plan modifications to resolve on-the-spot difficulties during construction. The goal of contract fulfillment is to complete a project efficiently, profitably and within specifications. This is where investment in technology can have an impact.

Our thesis is that construction technology is impacting the means and methods of wall and ceiling construction. We believe that how walls and ceilings are built is changing.

In preparing this report, we conducted dozens of original interviews with industry thought leaders, including

> **"Companies not on board the automation revolution will be left behind.**

[1] Definitions featured in Appendix 1: Glossary are adapted from several sources and modified by the report's author.

[2] Some technologies presented in this paper have been in use in the wall and ceiling industry for years. Others are in development. This report focuses on construction processes. We have not researched innovations in building materials.

AWCI member contractors, AWCI chapter presidents and manufacturers of building materials, construction tools and architectural products. We reviewed trade articles, news releases and available research reports.

PREVIEW OF CONSTRUCTION TECHNOLOGY IN USE

Several kinds of construction technology are currently in use. The 2019 AGC/FMI Risk Management Survey identified some of these technologies (See figure 1).

The AGC/FMI report makes the following conclusions:

- Specialty contractors are more likely to emphasize field-oriented technology tools, such as job site/mobile connectivity.
- General contractors are more likely to use project management software.
- Construction managers are most likely to use BIM.

USG Corp. and the U.S. Chamber of Commerce asked contractors to choose from a list of eight jobsite technologies for its Q4 2019 Commercial Construction Index (See figure 2).

Here are key take-aways from the USG/US report:

- 60% of contractors use at least one technology from the list; 80% plan to use at least one of these technologies by 2022.
- Drones and equipment tagging are the leading jobsite technologies.
- Wearable technologies, equipment tagging and RFID tagging are expected to surge by 2022.
- 3D printing and automated equipment/robotics have low levels of use, which is not expected to change by 2022.
- General contractors use advanced technologies more than specialty trade contractors.

Why Has Technology Become a Game Changer of Late?

Constructor, a publication of the Associated General Contractors of America, says that construction has been slow to adopt technology. FMI Corp. says construction firms invest only 1% of their annual revenues in research and development initiatives.

Constructor notes two reasons why the rate of technology adoption in construction has been slow over the years:

Construction operations are cash driven. Because they operate on thin profit margins, construction companies tend to prioritize the funding of tools, equipment and personnel before investing in new technology.

Contracting firms typically are family-owned and take a traditional view of work processes. Rather than look to

FIGURE 1.

The Top 10 Technologies Contractors Use to Manage Organizational Risk

Source: 2019 AGC/FMI Risk Management Survey

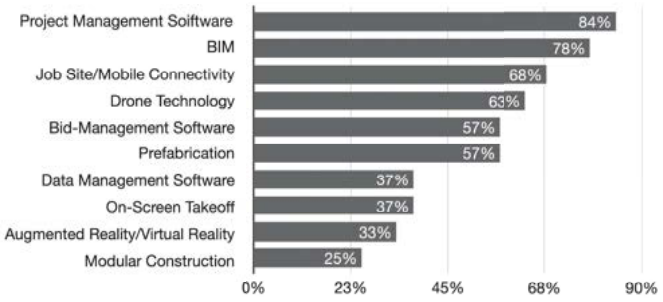
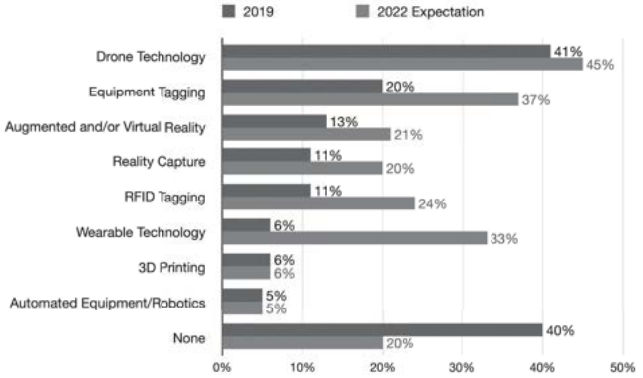


FIGURE 2.

Current and Future Use of Advanced Technologies on the Job Site by Contractors

Source: USG/US Chamber of Commerce Q4 2019 Commercial Construction Index



technology for solutions, many contractors like to solve problems using their own ingenuity. As a rule, contractors favor tried-and-true work processes rather than adopt new means and methods of construction, until such new means and methods become well established (See figure 3).

"Frankly, the contracting environment is not welcoming," says Jose Luis Blanco, partner at McKinsey & Company, as reported by Engineering News-Record.

Keep in mind, however, that the lack of R&D spending in construction does not necessarily reflect a lack of interest in technology. "We are a service industry, not a product industry," says K.P. Reddy of construction venture capital firm Shadow Ventures.

Technology companies have to market their products to senior construction executives and field personnel, trying to convince both about their products' benefits. "If you pitch a contractor with a great solution, they say, "Talk to a guy on one of our projects,'" says Reddy. "It's hard having to initially sell project by project to get momentum."

However, the construction industry is poised to adopt technology at a more rapid pace. Here are five reasons why construction technology investment is expected to accelerate:

A younger generation of executives who are less resistant to applying technology solutions to construction problems are taking the helms at many firms.

More general contractors and construction managers require the use of certain technologies as a prerequisite for bidding their projects.

Computing power, software interoperability and mobile connectivity have increased, making it easier for construction firms to set up and integrate software solutions.

Automaton is at hand. Laser scanners, drones, GPS tracking, RFID tagging, robotic automation and artificial intelligence make it possible to capture production data from the field and issue reports to management without human intervention.

Venture capital continues to fund construction technology startups, making more technology solutions available to construction firms (See figure 4 and 5).

FIGURE 3.

% of Annual Revenue the Engineering & Construction Industry Invests in Research and Development

Source: FMI Corp., 2019 Technology: Reshaping the Built Environment

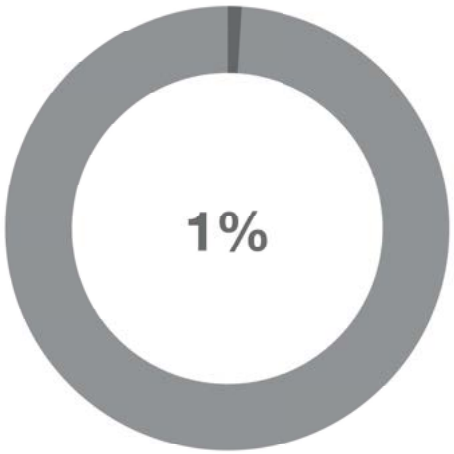


FIGURE 4.

Funding for Construction Tech Startups

$ billions

Source: Crunchbase News

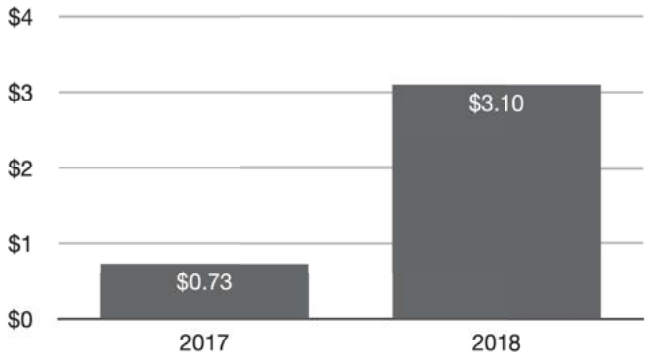


FIGURE 5.

Number of Different Technology Solutions Introduced to the Built Environment

Source: Jay P. Snyder, FMI Corp

Last 10 Years

2,000+

WHAT YOU WILL LEARN FROM THIS PAPER

Questions This Paper Will Answer

- How is technology changing the means and methods of wall and ceiling construction?
- Which technologies have the potential to disrupt wall and ceiling construction?
- How should wall and ceiling companies gear up for technology investment?

Overview of Our Findings

We make the following conclusions:

- Wall and ceiling contractors are acquiring both hardware and software.
- Prefabrication is a huge driver of technology adoption, especially among large AWCI member contractors.
- Data analytics and asset management will have a significant impact on the means and methods of wall and ceiling construction.
- Integrated software solutions will help AWCI member contractors work more efficiently.
- Benefits would accrue to AWCI member contractors if the entire AEC value chain could standardize the specification of common wall and ceiling types.

IMPACT OF TECHNOLOGY ON WALL AND CEILING CONSTRUCTION

Impact of Technology on Productivity

Construction productivity has declined since 1990, says the McKinsey & Company report, "Construction and Building Technology – Poised for a Breakthrough?" The report analyzed the performance of a global sample of 1,040 public construction and building technology companies and found that high fragmentation, low productivity and slow adoption of technology has caused construction to lag other industries in value creation.

Technology Impact on Construction in General

Technology investment is a top trend affecting the future growth of construction. "Technology is enabling greater operational efficiency," McKinsey says. Construction companies can expect to grow, McKinsey says, especially when they leverage these three technologies: data analytics, digital construction tools and robotics/automation.

Technology Impact on Wall and Ceiling Construction

The level of technology investment varies by wall and ceiling firm. Such firms exist "at different stages in their technological evolutions," says AWCI's Construction Dimensions.

Four senior directors and marketing managers at Hilti North America offered these observations about the wall and ceiling trade:

- Contractors are most concerned about an aging workforce, profit margin pressures and developing skilled labor and management.
- An aging field workforce does not always want to alter their existing workflows.
- Efforts to remove labor-intensive workflows is growing.
- Pre-formed solutions that reduce post-installed labor are growing.
- Means and methods of ceiling construction have changed little in the past few years.
- Innovations in ceilings focus on lighter and more robust

ceiling grid products that allow for wider spans and design options.

- Industry representation in prefabrication has grown from 2% to 5% in the last three years.

Based on additional interviews and media reports, we conclude that large wall-and-ceiling firms and firms with prefabrication operations tend to be further along the technology adoption spectrum versus small and medium-size firms.

- Large firms generally have more capital available for technology investments than small and medium size firms. Example: Some large AWCI member contractors have recently invested in prefabrication machinery, 3D printing and robotic/automation manufacturing technologies.

- Small and medium-size wall and ceiling firms have invested in cloud-based financial and project management software. Example: Some small and medium-size firms have converted their field reporting processes to digital document management platforms and are moving to adopt ERP systems.

Technological innovations are making wall and ceiling installation easier, faster and more cost effective, according to sources. For example:

Firestopping Technology. Bob Grupe, AWCI's director of technical services, sees innovation with the integration of firestop technology and cold-formed steel framing. As an example of this, Grupe cites CEMCO's new Fire Gasket, Fire Bead and Hotrod XL fire-rated deflection beads. The products have intumescent coatings enabling them to be used in lieu of fire sealant, saving subcontractors time and labor in installing a qualified fire-rated system.

Portable and Stationary Board Milling Machines. Grupe says today's job sites are moving some work away from stick-built processes, and technology is driving this change. Board milling machines, such as the Grabber PanelMAX, can prefabricate ceiling bulkheads and repetitive drywall shapes like chair rails, increasing crew productivity and trimming time off schedules.

Total Stations. Through software upgrades, the latest generation of construction total stations—both optical-based and camera-based layout tools—are easier to use for interior layouts and setup faster, say sources at Hilti.

Cordless Tools. Cordless tools are being designed for specialty applications and require less skill and training. They use interchangeable batteries, so one battery can be used across a tool provider's entire product line.

Internet of Things (IoT) and Data Analytics. IoT-connected power tools are becoming "intelligent" as tool manufacturers start making tool production and movement data available to subcontractors. Hilti sources say that this trend is especially relevant to the interior finishing trade and will help firms make better production management decisions.

Technology will have an impact on wall and ceiling crews and fabrication shops.

- CNC cutting machines, robotics/automation and 3D

FIGURE 6.

% of Project Managers and Field Supervisors Who Have Been Issued Mobile Devices

Source: FMI/PlanGrid 2018 Construction Disconnected Report

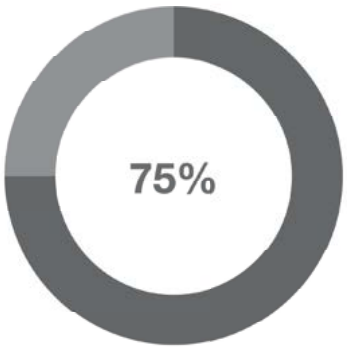
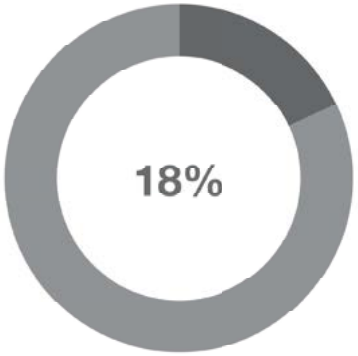


FIGURE 7.

% of Project Managers and Field Supervisors Who Consistently Use Mobile Apps to Access Project Data and Collaborate

Source: FMI/PlanGrid 2018 Construction Disconnected Report 2019 Commercial Construction Index



printing are used by other industries and are being adopted by some wall and ceiling firms.

- Digitalization of workflows, augmented reality layout and virtual reality (VR) safety training are still in development or are nearing field readiness. Still, some large and progressive wall and ceiling firms are researching and even piloting some of these technologies.

However, many construction professionals are dependent on paper documents for tracking, reporting and collaborating on projects (See figures 6 and 7).

Applied Technologies Currently in Use in Wall and Ceiling Construction

Integrated Software Solutions

Over the last 10 to 15 years, construction software has shifted from being budget and line-item applications to include project management, communications, collaboration, asset management and strategic planning applications.

Technology "has moved from being a consideration to being an enabler or even an actuator that allows firms to develop services and capabilities in their business that they otherwise couldn't create," says Jay P. Snyder, a technology practice leader with FMI.

These "services and capabilities" are provided by a "technology stack," a group of software products that process a series of functions—accounting, project management, estimating, quantity takeoff, time tracking, fleet management, customer relationship management, etc (See figure 8).

As they become more sophisticated, construction companies seek software to address more functions—document management, scheduling, safety alert management, reality capture, BIM integration and work in progress (WIP) management, to name a few.

"We have seen an explosion of construction-specific software—and a sharp uptick in technology adoption," says "Where Construction Firms Are Finding Value" from FMI/Procore.

"Technology … enables companies to efficiently organize data and business workflows to reveal vulnerabilities or areas for improvement; create financial, cost, and project controls to highlight areas of concern or business requirements; and automate reporting and trend analysis in operations, finance, and risk management that would otherwise be cumbersome to create," notes the FMI/Procore report.

However, technology stacks present challenges:

- It's hard to deploy a series of applications uniformly with construction workers deployed on multiple types of projects and in multiple locations.
- Some construction workers will adopt software technol-

THOUGHT LEADER

Robert Grupe
Director of Technical Services, AWCI

Q: Is technology affecting the means and methods of wall and ceiling construction?
Grupe: Yes. We are designing and erecting buildings far different than we did 15 years ago, maybe even 10 years ago. The change has been exponential, so in five years I think you'll see quantum leaps in wall and ceiling construction.

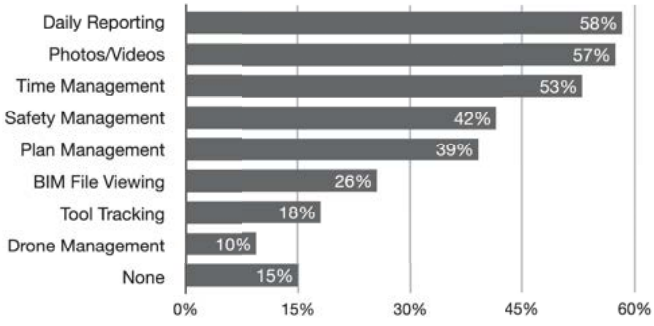
Q: What technology for the job site looks promising to boost productivity?
Grupe: On one end, you have BIM, which is getting to be old school these days. On the other end, you have robotics, and everything in between. On robotics, I'm not really seeing it. Yes, we have all seen some preliminary prototype robots laying brick and installing drywall. But to my knowledge it's not happening in the field. Using GPS coordinates for layouts—the total station concept, using iPads to designate locations where a wall or ceiling will be—is fairly common now and should continue to be used

Q: What's happening on the Construction Management Technology Committee of AWCI's Construction Technology Council?
Grupe: I feel the agenda of the Construction Management Technology Committee is in transition. There is a lot of chatter about panelization—about the codes and standards to meet the requirements of panelized and modular construction.

FIGURE 8.

Workflows Using Mobile Apps

Source: JBKnowledge, 2019 Construction Technology Report



ogy, but others prefer to use traditional analog methods.

- Construction data tends to exist in silos that sometimes requires re-entry into other applications, rather than populating other applications automatically.

FMI/Procore say that more than 90% of all data remains unused in construction.

"We know that some construction firms' organizational processes are outdated and not able to accommodate advances in data collection, management and analytics," FMI/Procore says. "But long-standing cultures … resistant to data-driven business models are also to blame."

Based on our research, construction companies have three options for deploying software:

- Assemble a technology stack of software applications.
- Subscribe to an all-in-one ERP platform that integrates various software functions. This approach offers less customizability than the "tech stack" approach.
- Combine a small "tech stack" with a technology service that warehouses data, provides some front-end software functionality (accounting, forecasting, WIP management) and uses the same data for all applications. Briq is a provider in this space.

The trend in construction software development, and what is desired by construction companies, is to integrate software solutions—the second and third options above.

"[Construction companies] want to be able to look at the data three-dimensionally and be able to drill into it," says AGC's Constructor. "ERP systems don't have that kind of capability, and as the amount of data companies have access to grows, so does the need to have a business intelligence platform to pull it together and generate analyses and models."

Impact on means and methods of wall and ceiling construction: Integrated software solutions are having an impact on wall and ceiling firm's estimating, construction processes, field productivity, project timelines, conflict resolution, worker safety and risk mitigation.

AWCI member contractors use either digital documentation software or plan to acquire such software. Some firms are upgrading their accounting and project management systems. Other firms have developed their own estimating and project management applications, rather than buy commercial software products. Still other firms are transitioning from basic "tech stacks" to ERP suites for estimating, proposal generation, job tracking, tool tracking, vehicle maintenance, financial tracking, safety programs, to-do lists and scheduling and more.

THOUGHT LEADERS

John Rapaport
Master Constructor/Company Attorney, Component Assembly Systems, Inc.

John Lord
Chief Information Officer, Component Assembly Systems, Inc.

Rapaport and Lord have pioneered the development of the Partition Information Exchange, an open-source library of partition wall types available free of charge to the industry.

Q: What is PARTie?
Lord: The Partition Information Exchange is a fulcrum for talking about wall types. The idea is not to force a library on anyone, rather it's a reference for all project partners, allowing them to speak one language.

Rapaport: We created PARTie to provide the wall and ceiling industry with stability and cooperation to meet the industry's common goals.

Q: How does it work?
Lord: Architects need a common language to refer to walls, since each firm typically has its own designations. A single stud, 3-5/8 wall might be called an "A-5" at one firm and a "B-2345" at another firm. PARTie unifies the standards and the language for specifying and constructing partition walls, so now all architects can order up a "Type A" wall and know that they will receive the exact wall on their project.

Q: How do you plan to get consensus for PARTie?
Rapaport: John and I traveled to Dusseldorf, Germany, to present PARTie at the 2019 BuildingSMART International conference. It was very well received, and BuildingSMART International has informed us that they plan to adopt PARTie as the wall type library for Europe. So, we are starting with Europe.

Next year, we plan to introduce PARTie to North America through the Building Information Management (BIM) Council, a part of the National Institute of Building Sciences Information and Technology Programs in Washington, D.C.

Q: How will PARTie help wall and ceiling contractors?
Rapaport: We have it teed up and ready to use at Component Assembly. It's nice to be able to watch the process play out with validation. PARTie is a way to standardize information for all specialty contractors. If we become the largest industry with a standards library, we become more powerful.

- These new data ecosystems can capture, store and analyze data. (See Data Analytics and IoT-Driven Data Analytics.)

- Software integration is helping industry firms "make better pricing, operations and marketing decisions," says an article in the March 2019 issue of AWCI's Construction Dimensions.

Total Stations

Construction total stations are surveying tools used for laying out interior wall framing and ceiling grid, especially on large projects and projects with curves, arcs, complex shapes and ceiling clouds. Generally, all construction total stations are robotic, meaning they allow remote operation. Only one operator is needed on site to layout points using a prism or a laser.

A wall and ceiling contractor's typical layout range is usually the deciding factor on which type of total station they purchase.

Optical-Based Total Stations. Optical-based units are an investment—$41,999[3] for the Hilti POS 180, for example. But, they can be operated by one person (who has had special training) and have a working radius of nearly 1,000 feet.

Camera-Based Total Stations. Camera-based robotic total stations are mid-range layout tools. The Hilti PLT 300, for example, covers a radius of 164 feet and is priced at $23,1693. Some camera-based units self-level, setup quickly on the job site and are becoming mainstream in the wall and ceiling trade.

Specialty contractors can use construction total stations with or without a BIM. However, from a coordination and accuracy perspective, there is a huge benefit for the wall and ceiling contractor to use a digital layout system that pulls from the same digital model as the MEP trades, so that floor penetrations, piping lines and other MEP runs all line up with the interior walls and ceilings, Hilti says. On-site efficiency greatly increases with the presence of CAD drawings, since the installer can walk to any point on a floor and the tool will "snap to" that point, a feature unique to Hilti layout software (See figure 9).

Impact on means and methods of wall and ceiling construction: Use of total stations in walls and ceilings is hard to pin down precisely. Senior directors and marketing managers at Hilti North America estimate that total stations are used on 10% to 15% of all interior finishing projects. Investment in total stations by small and medium-sized firms is growing. But, the use of construction total stations with BIM projects for interior layouts is not as high as other trades.

The following factors determine how total stations are used in wall and ceiling construction, according to Hilti:

- Capacity and skills to prepare layout files, upfront costs and having trained operators.

- Volume of work. Construction total stations are most common among large contractors, since payback on the tools comes quickly with volume.

- Prioritization of total stations on projects where they will have the largest impact. Even the largest contractors do not use construction total stations on all projects.

Building Information Modeling

BIM software is a virtual design and construction tool with many features, including the following:

3D Design. Contractors and fabricators can engineer assemblies and components and share them with other project participants.

Information. Models can contain project schedules, room-finish schedules, wall types, stud properties and more.

Clash Detection. Models help resolve conflicts between the architectural designs and as-built conditions and foster better collaboration among the trades.

Prefabrication Planning. BIM inputs can accelerate the construction timetable to meet aggressive project schedules.

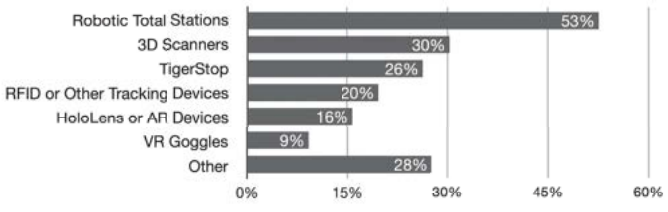
So far, the AEC industry has yet to develop a single platform for use by all players in the construction value chain. World Economic Forum says the benefits of collaborative platforms like BIM will materialize only if a "whole ecosystem is ready."

However, a company's ability to get up to speed with BIM can be difficult. "Due to [the] general complexity of information technology implementations, difficulties occur. To choose a [BIM] technology for [the] company's

FIGURE 9.

Hardware in Use

Source: JBKnowledge, 2019 Construction Technology Report



[3] Prices of Hilti brand layout tools were retrieved October 4, 2020, from hilti.com.

next spearhead tool, the road is usually long and rocky," says the Tampere University of Technology research paper, "Challenges of Implementing New Technologies in the World of BIM."

BIM also has its limits when it comes to the finishing trades.

"We thought 10 or 12 years ago, when BIM started sinking its claws into the earth and pulling the whole industry forward with all of its capability, that it would have the ability to go down to fine levels of detail. But I haven't seen it," says Robby Ball, computer aided design drafter at ceiling manufacturer 9Wood, Inc., in Oregon. "Whether it's a 1,000 sq. ft. ceiling or a 70,000 sq. ft. ceiling, adding the detail of where to place fasteners along the grid could literally crash everybody's machines."

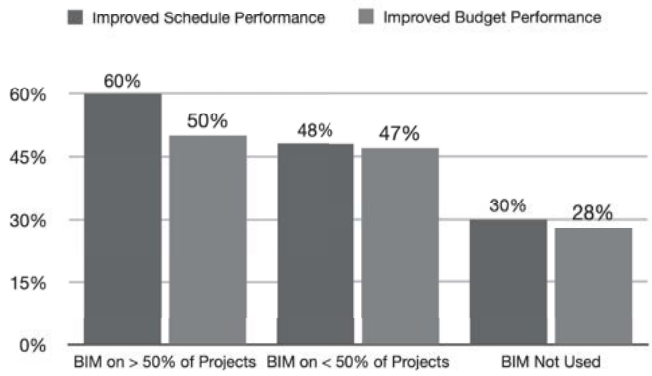
"BIM has helped the upfront planning. It gives building owners the ability to see their finished product. It has helped to create bills of material for rough budgets, and helped every trade to learn sequences and when they can work in parallel on different floors," says Ball. "When it comes to finishes, though, you have to work off of the as-built. Architects are not going to recreate their Revit models based on the drywall finishes and 3D site scans."

Even so, McKinsey says that 5D BIM, which combines 3D modeling with scheduling and budgeting, is one of six disruptive technologies affecting construction today (See figure 10).[4]

Impact on means and methods of wall and ceiling construction: A shift is underway to use 3D modeling for real-time project management, McKinsey says. Also, the design industry is beginning to issue 3D drawings rather than 2D drawings, according to Construction Dive. More and more, construction field documents will come directly from 3D models. Wall and ceiling firms will need to set up virtual design and construction departments, or contract with third-party 3D modelers, to use the 3D drawings in the field and in their fabrication shops.

FIGURE 10.

Impact of BIM on Schedule and Budget Performance
When Using BIM with Prefabrication or Modular Construction
Source: JBKnowledge, 2019 Construction Technology Report



As noted in the Foundation paper, "Prefabrication in the Wall and Ceiling Industry," AWCI member firms can advance virtual design and construction within the industry by doing the following:

- Identifying key BIM standardization topics.
- Participating in efforts to develop common BIM platforms.
- Participating in efforts to establish common BIM user interfaces.

"The more standard components we can pull from a library or other depositories—a fire-rated wall, a demising wall, a bathroom pod—the more commonality that architects can design to, we can build to, and we can prefab to, the more we start to see huge gains," says Travis Vap, CEO of South Valley Drywall.

Augmented Reality Layout Systems

Using AR software technology and AR headsets, such as the Microsoft HoloLens 2, a framer can see a 3D visualization of a plan projected in real time onto the slab or other surfaces. The framer can lay down real track and frame walls using digital inputs from a 3D model processed by the headset.

Observers say AR layout technology has yet to achieve the accuracy levels required in wall and ceiling construction. They say only construction total stations are accurate enough to do BIM-to-field layouts that meet industry tolerances.

"AR layout tools can do plus or minus an eighth of an inch—that's a total of one-quarter of an inch., which falls outside the ASTM tolerance," says Vap. "But the tighter those tools get, the more applicable it gets for us."

Impact on means and methods of wall and ceiling construction: The impact of AR layout is developing, since only a handful of wall and ceiling firms have piloted AR layout systems.

In 2016, a framer with Martin Bros. in California used

[4] McKinsey's list of disruptive technologies includes (1) modular construction, (2) drones, (3) 5D BIM, (4) 3D printing, (5) robotics and automation and (6) big data, artificial intelligence and IoT, technologies that process large data sets into useful information to enlighten future decisions.

AR layout technology to build a bathroom pod, relying completely on readouts from his AR headset and providing proof of concept.

In 2018, at AWCI's Convention & INTEX Expo in Orlando, Fla., two virtual design and construction specialists with BakerTriangle Prefab in Texas demonstrated they could manipulate a BIM in real time using a Wi-Fi connection and a HoloLens headset. Their in-house developed software repositioned studs in the model live at the conference.

CNC Machines for Cutting, Shaping and Folding Material

Some wall and ceiling firms look to manufacturing as a way to build assemblies and components. Prefabrication shops require machinery, and that calls for capital investment and the willingness to assume risk. Here is a list of some of these machines:

Laser Cutters and Plasma Cutters. Laser cutting directs a high-powered laser through optics to cut metal. Laser cutting can produce complex metal geometries and parts with smooth edges. Laser cutters can cost between $300,000 and $500,000, one source says. Plasma cutting is for cutting thick metal plates. Advanced CNC software running both machines ensures that parts can be arranged in a sheet to minimize scrap.

Press Brakes. Multi-axis press brakes bend, fold and form metal sheets. The machines can exert a force of 100 to 200 tons and can produce nearly identical parts on high-volume batch runs. Press brakes can create a variety of metal parts for client projects.

Automated Roll-Forming Machines. Roll-formers enable contractors to produce their own cold-formed steel studs and track. The machines and related software pre-engineer, cut and label steel components for wall, truss and flooring systems. The software produces a list of the formed components for untrained laborers to assemble. Roll-formers give construction firms[5] vertical integration, as they buy steel coil directly and produce framing components. Automated roll-forming machines can cost $500,000 to $800,000, one source says.

Portable and Stationary Board Milling Machines. Machines, such as the Grabber PanelMAX, can prefabricate ceiling bulkheads and other repetitive drywall shapes. Some bridge saws automatically pull in sheets of drywall, cut grooves into the core material and fold and glue the boards to form complex fur downs and simple corners.

Impact on means and methods of wall and ceiling construction: The impact of these machines is significant. Many AWCI member contractors now machine metal components, roll their own steel and produce custom drywall shapes. They say such fabrication technologies have increased crew productivity and trimmed time off construction schedules.

Fabrication machines are helping the industry to move work away from traditional stick-built processes. Milling machines, for example, can eliminate some finish work in the field. Prefabrication can reduce the labor hours and make a wall and ceiling company less affected by the skilled worker shortage. AWCI member companies report sending teams to attend fabrication technology trade shows to see first-hand the latest manufacturing automation.

3D Printing

3D printing is a form of additive manufacturing used to create building components and structures. The technology offers many benefits, including reduced material usage and productivity gains of up to 80%, according to World Economic Forum. Components such as walls can be 3D printed in a matter of hours.

The McKinsey "Construction and Building Technology" report says that 3D printing is one of six disruptive technologies affecting construction today.

Impact on means and methods of wall and ceiling construction: We know of one AWCI member prefabricator using 3D printing in its operations, South Valley Prefab, which is 3D printing finishes for exterior panels. Other AWCI member contractors have purchased 3D printers. None have found them useful for field construction.

"Some metal additive printing might be good for our manufacturing shop if we need to replace parts in a tool or make small custom tools," says California Drywall's Eckstrom. "But, it really has not had a bottom-line effect on my business."

3D printing full-scale walls and ceilings for commercial projects is not likely to happen anytime soon, according to AWCI's Construction Dimensions. Some firms might use 3D printers to create models of prefabricated components or miniature project mock-ups that could help stakeholders visualize the final as-built structure.

Drones

Drones, also called unmanned aerial vehicles (UAVs), are autonomous flying machines that help construction

[5] Published reports show that even small framing contractors invest in automated roll-forming equipment. According to a 2018 Steel Framing Industry Association case study, "Modern Erector Set: Pole Barn," Straight Cold Rollin, LLC, of Wyoming used Keymark Enterprises' wall framing software and truss design software, a roll-forming machine and "three untrained laborers and a local fireman with minimal building experience" to produce a 60-by-140-ft. pole barn in about two months.

companies track, map, survey, inspect, verify and manage worksites. Drones are used in commercial construction principally for progress monitoring, logistics and marketing.

Most construction drones carry sensors—cameras, depth sensors and 3D scanners—to monitor work output. Their usefulness is linked to the quality of these sensors.

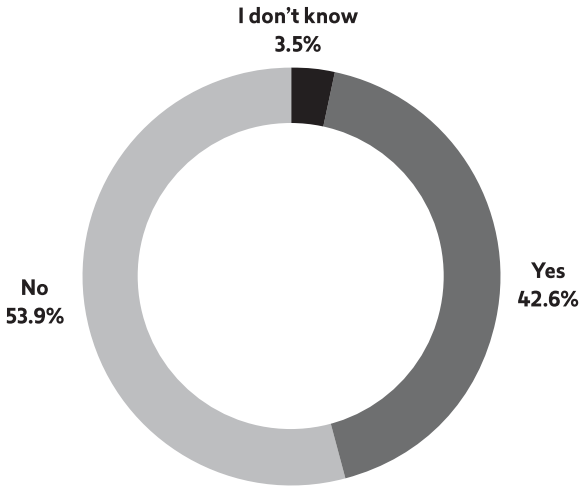
- Sensor data can be fed into the project building information model to run percent-complete calculations, estimate material stock needs and track personnel movements.
- Some GCs use drones outfitted with cameras to verify that site workers are complying with physical distancing safety protocols.
- Research is underway to use drones to deliver payloads. The University of Michigan is developing UAVs that can fly in and nail shingles to a roof, for example.

Drones enable real-time remote data capture and monitoring and provide access to remote and dangerous areas. The McKinsey "Construction and Building Technology" report says that drones are one of six disruptive technologies affecting construction today.

Impact on means and methods of wall and ceiling construction: Even though drones can serve as reality capture devices, they have had limited use in wall and ceiling construction. Few wall and ceiling firms have purchased drones for use on projects. "Drones are for marketing," says an AWCI member contractor. "I don't see how it applies to my construction."

FIGURE 11.

Does Your Company Use Drones?
Response of Contractors Surveyed
Source: JBKnowledge, 2019 Construction Technology Report



In general, construction drones are not being used for their payload capacities, according to Hilti. Rather, traditional methods for moving material, such as cranes and elevators, have greater capacities and reach, and are still favored on job sites (See figure 11).

Despite their perceived low barrier to entry and affordability, drones require technical skill to operate and knowledge of local and federal use regulations.

Thus, construction drones are not impacting the means and methods of the wall and ceiling trade. None of the wall and ceiling executives interviewed for this report said their firm uses drones in their production processes.

Reality Capture

Reality capture—also known as high-definition surveying and 3D laser scanning—uses a laser to capture 3D as-built data of a construction site. The systems typically include a laser scanner, mapping software and a mobile cart (or a drone).

Reality capture with robotic cameras integrates with BIM software to monitor, live stream and continuously record job sites. The technology generates a point cloud database, an extremely accurate digital record of objects and spaces. The systems provide these functions:

Design. As a project starting point, reality capture provides a scan-to-BIM method of design.

Conflict Avoidance. Reality capture helps to identify potential conflicts among HVAC, electrical, plumbing and wall and ceiling assemblies.

Documentation. Reality capture can document milestones, change orders and installation errors and create a permanent, as-built record for future building operations.

Analytics. Scanning as-built conditions can help teams develop more detailed workflows and, by streaming processes, reduce job costs.

An Autodesk construction blog says reality capture is becoming a staple on construction sites around the world. The annual growth rate for the 3D imaging market in construction currently is about 15% and is projected to be valued at $10 billion by 2024, according to POB magazine.

Impact on means and methods of wall and ceiling construction: Though it offers many benefits, reality capture is costly to implement, according to Autodesk. Sources say reality

[6] See the book, AWCI's Celebrating 100 Years of Industry Growth with the Association of the Wall and Ceiling Industry, page 193.

capture has not yet had a significant impact on wall and ceiling construction, although some firms are investing in the technology.

Eckstrom says California Drywall is obtaining Trimble laser scanners for site walk-throughs. The scanners will capture existing walls and MEP installations and create "a model to within 1 mm or 2 mm," Eckstrom says. Building off of a building information model, the scanners can measure deck heights to order steel studs pre-cut to length and also identify construction errors in the as-builts.

Autonomous Construction Robots

McKinsey's "Construction and Building Technology" report has identified robotics and automation as one of six disruptive technologies impacting construction. The technology is being developed to fulfill predictable physical tasks in construction.

The goal is to increase output and decrease variable labor costs. USG has said that automation will "upskill" the workforce by relegating repetitive, mundane and risky tasks to robotic technologies.

Autonomous construction robots can play a significant role in production and quality control workflows by enabling the automation of routine and tedious tasks, reducing workload and improving safety. Here are some examples of autonomous construction robots:

Spot Robot. In November 2019, Boston Dynamics, Hilti and Trimble announced a collaboration to integrate Boston Dynamics' Spot Robot with Hilti's and Trimble's construction management software, Global Navigation Satellite System technologies and reality capture devices. Spot Robot has terrain-agnostic capabilities, which means it can work around obstacles. Equipped with Hilti and Trimble's reality capture devices and cloud-based communications, the Spot Robot can scan job sites, monitor as-built progress and provide remote support to workers.

Jaibot. In November 2020, Hilti introduced Jaibot, a semi-autonomous robot that can drill into overhead concrete decks. Jaibot uses BIM data to locate itself indoors, drill holes and mark the holes according to the corresponding MEP trade.

Impact on means and methods of wall and ceiling construction: South Valley Drywall is on the cutting edge of robotic technology. Its prefabrication company, South Valley Prefab, currently has three automated machines operating in its panel manufacturing plant. A fourth machine is expected to be in place in early 2021. One machine applies final finishes to prefabricated exterior panels, doing in 30 minutes what six men by hand do in four hours.

California Drywall's prefabrication facility has leased a robotic welding cell. Though still assessing its value, Eckstrom believes robots will be field ready in two or three years.

Some industry executives, however, see greater value in refining existing processes. "We break down the construction of a wall—from metal studs to finish plaster—into a two-hour process. One panel moves through our shop every two hours," says David Keane, VDC specialist and project engineer at Baker Triangle Prefab in Texas. "Our focus has been to cut the processes down, rather than deploy more technology and equipment to do that."

Asset Management

Asset management makes use of tagging and IoT technologies to help contractors process location and consumption data associated with their tools and equipment. The applied technologies available to help with asset management include:

Radio Frequency Identification. RFID is a wireless system comprised of tags and readers long used by industry to identify and track assets.

Barcoding. Barcoding is the most broadly applied technology in asset management, according to Hilti sources.

Bluetooth. Signal tracking using Bluetooth technology is proving to be sustainable, Hilti says, and is gaining usage in construction.

Impact on means and methods of wall and ceiling construction: How far along are wall and ceiling firms in adopting asset management technologies such as barcoding and signal tracking? Hilti says asset management is still in its early phase in drywall and interior finishing, partly because the trade does not normally need to manage many high-volume assets of significant value.

However, Hilti sees the number of tools increasing in the wall and ceiling trade. As interior finishing teams and their production processes become more specialized and kitted, the need to manage assets will become greater. Hilti also sees asset management being adopted as an approach to tracking prefabricated and partially fabricated assemblies.

Data Analytics and IoT-Driven Data Analytics

Data analytics involves counting work put in place and comparing results to a baseline. The analysis helps a firm know where its workflows are productive and how they can be improved.

An important area of development involves the Internet of Things. Manufacturers are beginning to connect their asset management systems with software that will give contractors the ability to pull production data directly from their IoT tools. Tool manufacturers believe this data can be used to analyze production trends and worker behaviors. Data derived from tools will soon be a feature made available by tool manufacturers as part of their asset management services.

However, since the data derived from tracking assets can be complex, manufacturers will be challenged to deliver data in a fashion that enables the contractor to easily derive insights on their businesses and field processes. "We're working with customers to better understand how much the data needs to be contextualized to create value," said Eric Hollister, senior director, marketing, electric tools and accessories at Hilti North America.

Impact on means and methods of wall and ceiling construction: The wall and ceiling trade has one of the most directly translatable data-to-production measurements among the trades, according to Hilti. Contractors could track data points, such as "nails installed" and correlate the figures directly to the amount of work done. Such data analysis would give wall and ceiling companies actionable insights from their production rates and enable them to impact their future bidding, workflows, skills training, proper physical distancing of workers and more.

IoT-driven data analytics is not in place in the wall and ceiling industry. Tool manufacturers are monitoring the space and view asset management, and the production data derived from tool usage, as two of the next big productivity drivers for construction contractors.

Some wall and ceiling firms track their data, analyze workflows and make informed decisions about their construction and manufacturing processes. "We can harvest data, see where we are at, see trends as we do the job—where we are making money and where we are losing money," Vap says. "We can see a job being fractured because of poor planning, or a trade not staffing up, and let the client know that impacts their schedule."

Artificial Intelligence and Machine Learning

Construction stands to benefit from the advent of artificial intelligence (AI) and machine learning, says Autodesk University. AI is a broad field of science concerned with programming computers to do tasks that normally require the input of human intelligence. So, AI is not just about automating processes, but about applying rational and decision-making to analyzed processes.

With the digitization of construction drawings and documents, and the interconnectivity of cloud-based software, AI applications stand to bring about construction efficiency by impacting the constructability of designs, the ability to identify safe and unsafe behaviors on sites and ways to optimize production processes.

Machine learning is a subset of AI that deals with writing algorithms. Algorithms allow computers to "learn" from data, without being explicitly programmed, to identify patterns useful for project teams setting schedules, ordering materials and deploying crews.

Impact on means and methods of wall and ceiling construction: At this time, AI and machine learning are not having a big impact on the wall and ceiling industry. But they could impact the industry within a few years. AI and machine learning will improve project scheduling by learning from past project data, flagging issues that could lead to delays and recommending production performance improvements.

- Some rudimentary AI tools target the wall and ceiling industry. The AI tools use photo recognition technology to analyze captured job site images and determine the rate at which work is being completed. SmartTrack software from StructionSite, for example, has been designed specifically for the framing and drywall trade, according to Construction Dive.

Near term, the biggest impact of AI on construction will be in safety. AI tools can track and analyze worker movements and determine whether they're using equipment correctly.

Safety Systems

Wearable GPS Trackers and Safety Alert Systems

Wearable GPS trackers and safety alert systems inform project managers and workers in real time about potential job-site safety hazards, including COVID-19-related alerts. This category of safety systems includes several types of wearables and safety check platforms.

GPS Tracking Helmets and Vests. These wearables contain multiple sensors and personal alert devices. They can detect when employees remove their face masks for an extended period of time or get close to other workers on the job. The devices remind workers of protocols and alert their managers.

Safety Check Platforms. Safety check platforms distribute health and safety messages to employees, allowing managers to tailor the messages and track their effectiveness. The platforms also remind employees to file their safety certifications with authorities.

Products include CrewMinders' safety check platform, eCompliance EHS safety management software, Everguard.ai Sentri360, Triax Technologies' Proximity Trac and more.

Wearables technology is being developed to track employee movements during construction. Movement data can be analyzed and lead to more efficient ways to stage materials, deploy crews to minimize trade conflicts and locate crews in the event of emergencies.

Some have asked whether tracking construction workers' movements on job sites and maintaining that data creates any liability or privacy issues. This remains to be seen. But sources say the unions are participating in discussions about safety tracking and that anonymity can be maintained by using privacy technologies, such as blockchain.

Impact on means and methods of wall and ceiling construction: Wearable safety technologies are expected to have a big impact in wall and ceiling construction, though AWCI members say the platforms and wearable devices are still under development.

- These technologies may help lower insurance premiums. "I may be able to convince my insurance company to help foot some of the bill to buy these wearables," says Cameron Wies, estimator and lead technologist at T.J. Wies Contracting, Inc. in Missouri.

- Safety vests with embedded RF nodes and connected to GPS technology will signal safe and unsafe areas on a job site.

- Prefabricators expect wearables to improve safety and productivity in their operations. "We might be able to see if workers are getting dehydrated or suffering from heat exhaustion," says Mike Potter, vice president at The Raymond Group in California.

Virtual Reality Safety Training

VR safety training uses computer software and special sensory headsets to create real environments and scenarios for fully immersive, realistic and interactive training. Mainstream computers, graphics cards, processors and VR headsets have become powerful and affordable, so that companies can implement their own VR training programs.

> "I may be able to convince my insurance company to help foot some of the bill to buy these wearables.

Autodesk University courses have shown that Revit and some additional rendering software can be used to create VR safety simulations, such as barrier construction, hole and trip hazards, spills and slips, ladder safety, rigging safety, weather-related site hazards and more.

AGC's Constructor says VR safety training is an ideal way to place trainees in realistic job site hazard scenarios—"seeing" cranes hoisting large objects overhead, "experiencing" sheets of drywall falling from above—and see trainees react.

Purdue University and MindForge have developed VR simulation training for OSHA and VR signaling safety training for the American Contractors Insurance Group's Life-Saving Commitments initiative.

Impact on means and methods of wall and ceiling construction: VR training modules are beginning to have an impact in wall and ceiling construction. AWCI member contractor companies report test-driving VR training modules provided by scissor lift and boom lift companies. Some firms have used VR to provide welding training, scaffold training and first aid training. Industry safety directors interviewed expect to see VR training modules coming soon for training workers in cold-formed steel framing, drywall hanging and finishing.

Exoskeletons

Exoskeletons are a form of wearable human augmentation that can reduce strain and fatigue for users and enhance their physical capacity.

The design of construction exoskeletons is evolving. The once bulky, mechanical suits have transitioned to smaller wearables that respond better to the worker's movement using springs and hydraulics.

The Center for Construction Research and Training (aka, CPWR) has found that the rate of work-related musculoskeletal disorders in construction is 11% higher than that for all industries. CPWR has a 2020 research project underway to study the effects of exoskeletons on trunk and arm support. The researchers expect to assess the safety, effectiveness and efficacy of exoskeletons for targeted tasks, which includes hanging drywall overhead.

In August 2020, Hilti introduced the EXO-O1 wear-

able exoskeleton in partnership with Ottobock, a global market leader in prosthetics and orthotics. Worn like a backpack, the four-pound EXO-O1 is designed to alleviate 47% of the stress of lifting arms over head, according to Construction Dive.

From the Hilti perspective, exoskeletons are part of the labor conversation. In North America and around the globe, construction is experiencing extreme labor shortages. Contractors are looking to leverage technology to retain their tenured skilled trades people and attract the next generation. Exoskeletons, along with other augmentation and assist technologies, help accomplish these objectives. They relieve strain and reduce fatigue for team members performing demanding applications over a workday.

Impact on means and methods of wall and ceiling construction: The impact of exoskeletons in the wall and ceiling industry is minimal, because few AWCI member contractors have purchased units. Sources say exoskeletons can cost $5,000 a unit.

AWCI member contractors that have purchased or trialed exoskeletons say their field workers prefer not to use them. The devices make the workers feel constrained on the job, and they are hard to transfer from worker to worker, since they are calibrated to fit each individual.

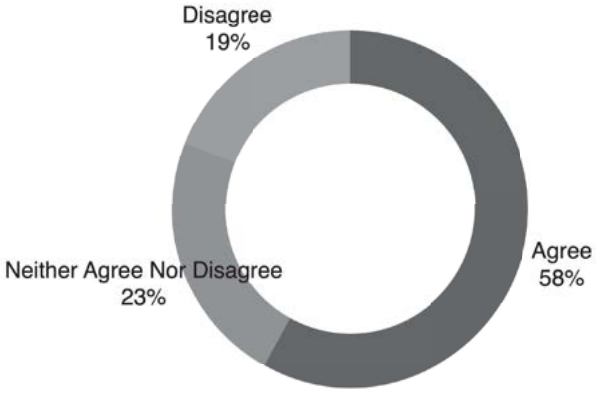
"It might have a future, not on a large scale, but for specific tasks—someone doing overhead work and holding a heavy tool, or someone drilling into concrete deck all day," says Eckstrom of California Drywall, which purchased an exoskeleton two years ago.

FIGURE 12.

Agree or Disagree: There Will Be More Change in How Construction Is Put in Place in the Next 5 Years than in the Last 50 Years Combined

Response of Contractors Surveyed (rounded)

Source: 2018 AGC/FMI Industry Risk Survey



Factors Driving Future Technology Adoption

Most contractors—80% according to the 2019 AGC/FMI Risk Management Survey of 2,500 contractors—say that the limited supply of skilled craftworkers is the biggest risk they face. The skilled labor shortage is one of the biggest drivers of future technology adoption. Two other important drivers include information exchanges and worker safety (See figure 12).

Information Exchanges

Information exchanges will likely have a direct bearing on the construction industry's continued adoption of modeling, estimating and project management technologies and will no doubt impact the means and methods of wall and ceiling construction.

Exchanges give the entire AEC industry one set of standards for specifying and constructing assemblies, so that what is ordered up by the designer is exactly what gets built in the field or in the fabrication shop—a Type A wall is always a Type A wall for all projects. An information exchange enables everyone—from architects to take-off jockeys to spec writers—to work off of the same base property sets.

One such exchange is the Partition Information Exchange, or PARTie. PARTie is a free, open-source library of standardized wall types pioneered by John Rapaport and John Lord of New York-based Component Assembly Systems, Inc., which has the Creative Commons copyright to the library.

PARTie includes definitions of more than 500 interior wall types, including standard single-row stud walls, double-row stud walls, shaft walls, furred wall conditions and more. Information for each wall type includes its fire resistance, sound rating and stud size, spacing and structural performance.

Functionally, PARTie is a database. It contains the data for cold-formed steel studs in various widths and gauges, multiple wallboard types and thicknesses, insulation, soundproofing elements, finishing treatments and other variables. Because the data follows the Industry Foundation Classes (IFC) 4 Step format, it can be interpreted across all platforms. That means wall and ceiling contractors can receive and/or upload PARTie data into their modeling software, estimating applications or Excel spreadsheets.

The PARTie library also includes Revit details—objects that can be used in project building information models, giving architects, engineers and contractors one set of standards to collaborate on partition designs.

"These standardized wall assemblies can be communi-

cated electronically on all platforms and by all segments of the industry," says Robert Grupe, AWCI's director of technical services and the consultant who compiled the PARTie database. "Architects, general contractors, wall contractors, building officials, product manufacturers—everyone will be able to speak one common language."

Using PARTie, designers can explore and select standardized wall types based on required system performance attributes. Their selections will communicate freely, in the IFC4 format, to all parties on a construction project, helping all realize not only 3D modeling benefits, but also data modeling benefits, such as the exchange of scheduling and cost information if they wish.

Impact on means and methods of wall and ceiling construction: Component Assembly Systems recently released PARTie to BuildingSMART International, which plans to adopt the partition standards for architects, engineers and contractors in Western Europe. In 2021, Rapaport and Lord plan to release PARTie to North American users, through the Building Information Management Council, a part of the National Institute of Building Sciences Information and Technology Programs in Washington, D.C., and possibly by working through organizations like the AWCI/FWCI, SMACNA, ASHRAE and others.

"If we become the largest industry with a standards library, we become more powerful, says Rapaport. "PARTie puts us in front of the architects, engineers and general contractors to exchange information in the first prime constructor industry besides the steel and steel detailers industry."

PARTie had originally been developed as WALLie (the Wall Information Exchange) in 2015. It was not submitted for any consensus approval at the time. Now, however, the timing of PARTie seems right as designers and constructors are better aligned through BIM and other software systems that have true interoperability. The growing use of panelization and prefabrication by wall and ceiling firms will also make PARTie a useful collaboration and production tool.

"You have a confluence of building technologies and construction processes happening right now," Grupe says. "PARTie can be the center of them all."

"These standardized wall assemblies can be communicated electronically on all platforms and by all segments of the industry.

Worker Safety

The FMI/Procore report cited earlier says that safety performance "is perhaps the most critical component for a contractor to maintain their license, secure affordable insurance coverage, obtain bonding, prequalify for projects, and recruit and retain talent."

"Maintaining a safe jobsite" is the top concern of contractors, according to the FMI/Procore survey of 738 industry leaders, which included 600 general contractors and specialty contractors. Most firms, 51.4%, say that construction software helps to maintain a safe job site. FMI/Procore make these additional points:

- Clear and timely communication is essential for maintaining a safe job site—and can be improved dramatically with technology.
- Good mobile accessibility, empowers field teams to quickly report any potential safety issues.
- Safety data collected through the software—from inspection reports, daily logs, incidents and corrective actions— can identify trends and help address safety issues proactively.

The USG/US Chamber of Commerce Q4 2019 Commercial Construction Index reports that 60% of contractors believe wearable technology has a high potential to improve safety—22% believe automated equipment and robotics will also be useful in addressing safety (See figure 13).

Impact on means and methods of wall and ceiling construction: Based on our research, job site safety is one of the largest drivers of technology investment among wall and ceiling firms. The impact of safety on wall and ceiling construction includes work processes, risk mitigation, recruitment and safety training.

AWCI member contractors are improving safety through several methods:

Safety management software. Marek Brothers in Texas uses the cloud-based eCompliance EHS software to track certifications for each of its employees—OSHA 10, OSHA 30, CPR classes, first aid training and equipment training. Previously, the company used Excel spreadsheets for this record-keeping, says Jorge Vazquez, safety director at Marek Brothers.

GPS trackers. J&J Acoustics in California has used wearable

GPS tracking technology when required by the general contractor. Rick Wood, superintendent at J&J Acoustics, says his firm is researching GPS trackers for production management and for safety management. "Safety-wise with GPS, we can tell what floor the workers are on, and how many flights of stairs they are walking in a day," Wood says.

Prefabrication. Technology that enables fabrication processes and reduces man-hours also reduces the risk of injury for workers, says California Drywall's Eckstrom. His strategy is to find technology that can reduce the labor count, which thereby increases safety performance.

New and Noteworthy Construction Technologies

BIM CAVEs and BIM CUBEs

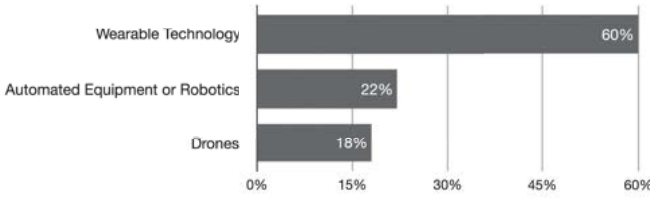
A BIM CAVE (Computer Aided Virtual Environment) and a BIM CUBE (Collaborative Ultimate Building Environment) are virtual reality (VR) projection systems used to experience building structures and spaces virtually, in three dimensions and on a human scale.

The Wall And Ceiling Alliance in Pleasanton, California has developed the WACA BIM CUBE, a mobile, standalone room that projects 1:1-scale visualizations of a client's built environment onto two 13'-by-20' walls. The WACA member can make design and layout changes in the BIM authoring tool, which reflect instantly in the visualizations.

FIGURE 13.

Top Technologies for Improving Job Site Safety

Source: USG/US Chamber of Commerce Q4 2019 Commercial Construction Index



The BIM CUBE's goal is to develop "the partnership aspects of the BIM experience," says WACA CEO Frank Nunes, cited by Walls & Ceilings. A CUBE can help specialty contractors become more comfortable with BIM and increase their involvement in early project design.

Impact on means and methods of wall and ceiling construction: VR projection systems are still in development. BIM CAVEs and BIM CUBEs appear to offer value to the specialty contractor, especially when development costs are shared by a contractor association.

- California Drywall used the WACA BIM CUBE for

THOUGHT LEADER

Travis Vap
CEO, South Valley Drywall

Q: Are the means and methods of wall and ceiling construction changing?
Vap: Yes, over the last 10 years the means and methods of wall and ceiling contractors have been changing and will continue to change. We have seen this change through BIM, robotic total station layout, augmented reality, virtual reality, digital scanning, ERP software, quantity take off, various field apps and other technologies.

On the installation side, we are seeing our trade consistently kitting framing, pre-cutting drywall, drywall milling, prefabricating and getting into modularization. The technology that is available to us today versus 10 years ago is pushing our industry forward. All of these things are driving benefit to our clients and driving positive change in our industry.

Q: What technologies are leading the way in this change?
Vap: I feel BIM has been the technology leading the way for the last 10 years and will continue to lead the way. The more we can use the model, the more innovation and productivity our industry can deliver, and the more value we can drive to our clients and our companies.

It is fascinating to watch what Autodesk is doing in gobbling up companies and combining software technology—AutoCAD, Revit, Fusion 360 or Fusion Lifecycle, Maya, 3ds Max, Inventor, InfraWorks, BIM 360, Alias, Autodesk Drive, Autodesk Rendering. Having a technology company combine technologies under their platform will encourage architects to design to a consistent standard. Specialty contractors then will then see increased productivity and efficiencies because everything is being funneled through that platform.

Q: South Valley Drywall is on the cutting edge of technology. What's new at your firm?
Vap: Our prefab company, South Valley Prefab, is doing some extraordinary things. We currently have three automated machines in our panel manufacturing process and have a fourth machine being delivered early in 2021.

One of our machines, which we have invented, is fully robotic and applies the final finish to our panels. We are able to do in 30 minutes took six men four hours to do by hand. The quality, speed, accuracy and predictability we are able to achieve through our machines and processes is unbelievable.

As we continue to progress we have a vision to 3D print any finish desired onto our exterior wall panels. We have already started prototyping this technology, and it will be exciting to see what we can do.

a recent hospital project. "The client could 'see' their patient rooms in a life-size, 1-to-1 ratio," says Eckstrom. "No one had to wear goggles."

- J&J Acoustics in California has used the WACA BIM CUBE to showcase its work with clients. "We 'walk' a project and see how the building framing and interior will look," says Rick Wood, superintendent at J&J Acoustics.

BIM CAVEs and BIM CUBEs will have an impact on construction processes, field productivity, conflict resolution and client relationships. VR projection systems will also drive future BIM technology adoption.

Laser Layout Projectors and Layout Robots

The next phase in the evolution of construction total stations synchronizes BIM with laser projectors and layout robots to mark construction drawings on the job site slab. Such devices eliminate the step of snapping chalk lines when laying out wall framing.

- The FramR laser layout projector from Mechasys, a startup founded in 2018 in Quebec, is accurate to 3 mm and can be operated by one person.

- Dusty Robotics' FieldPrinter service integrates BIM CAD drawings with a layout robot to print lines directly onto the slab, doing so 10 times faster and more accurately than traditional layout methods.

Impact on means and methods of wall and ceiling construction: Laser layout projectors and layout robots will impact wall and ceiling construction processes, field productivity, project timelines and work quality.

AWCI member contractors have made inquiries with the above-named companies and even piloted their products. However, sources say these technologies have accuracy and range limitations, and that further development is needed before they are field-ready for large-scale, commercial wall and ceiling construction.

Photogrammetry

Some AWCI member contractors are keeping their eye on photogrammetry, which is the science of extracting 3D information from photographs.

Autodesk says photogrammetry involves taking overlapping photographs of an object or space to create accurate 2D and 3D point cloud drawings. Photogrammetry achieves the same level of accuracy of traditional digital scanning, but with fewer data points. Thus, the technology can create accurate models of construction sites, but without excessive digital "noise."

- Pointfuse software can take point clouds generated by laser scanners or photogrammetry applications and convert them to manageable models and automatically classify building features to aid with clash detection.

Impact on means and methods of wall and ceiling construction: Some general contractors are using photogrammetry as part of their virtual design and construction processes. AWCI member contractors have expressed interest in the technology to connect reality capture with digital construction. In time, photogrammetry will impact wall and ceiling construction by improving construction processes, field productivity, conflict resolution, delay avoidance, material reduction and worker safety.

RECOMMENDATIONS

An MIT Sloan Management Review report, which says that companies refraining to use technology to solve problems risk a three-fold drop in revenue versus firms investing regularly in technology solutions. Thus, wall and ceiling firms need to prepare to invest in technology (see Figure 14).

1. Identify Problem Areas Where Solutions Are Needed

Wall and ceiling contractors say that right now schedule compression, poor inter-trade coordination and a skilled worker shortage are large factors affecting their work. Technology solutions can help alleviate some of these problems. Here is what to do:

Form a technology committee. Study your processes and workflows to identify bottlenecks, problem areas and inefficiencies.

Commission process and workflow studies. Research how your different departments use software, data and reports. Contract with a production engineering firm or task an internal team to track worker movements on job sites and in fabrication shops and identify problems and process inefficiencies.

Develop a business-use case for technology. Focus on identified problems to ensure that technology solutions address those problems. Ensure that the magnitude of a given problem matches the scale offered by the proposed technology solution.

2. Drive Technology Adoption from the Top

Wall and ceiling company executives say that successful technology adoption requires a clear vision of how to get

all company stakeholders working from the same technology playbook.

Gain C-suite buy-in. Ensure that top company executives, especially the company president and/or CEO, are ready to champion investment in technology to solve business problems.

Develop a technology adoption strategy. Ensure that your technology initiatives align with this strategy. Refer back to this strategy document before making any technology investment.

Establish and promulgate your technology vision. Use open communication to encourage all employees to understand, embrace and participate in the company's technology adoption programs.

3. Involve Your Entire Organization in the Technology Adoption Process

When adopting new technologies, companies will need to have in place an appropriate change-management process.

Expand your talent development mandate. Make it your goal to hire more IT people and more Virtual Design and Construction specialists.

Prepare case studies. Prepare short videos or write-ups showing how proposed technology initiatives, if adopted, could create value for workers.

Be open to everyone's input. Invest in technology when employees see value in the proposed acquisition. At the same time, postpone a proposed technology investment when employees seem overwhelmed by initiatives or are undergoing innovation fatigue.

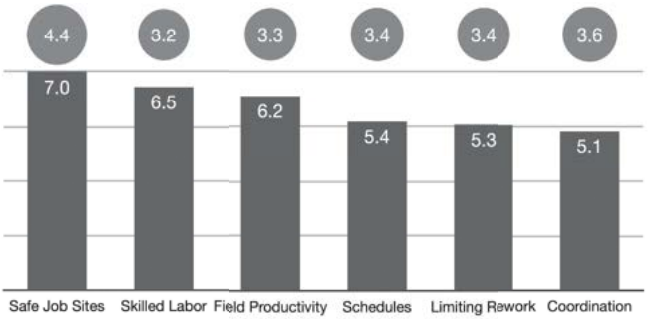
FIGURE 14.

Top Concerns and How Well They're Being Handled

Bubble represents rank of how well construction companies handle each business concern.

Bar represents rank of each item's relationship to future success.

Source: Adapted by the author from FMI/ Procore 2020 Industry Report



CONCLUSION

Key trends

- A shift is underway to using building information modeling for real-time project management, according to McKinsey.
- Data analytics and asset management are two of the next big productivity drivers for wall and ceiling contractors, according to Hilti.
- Automated roll-forming machines and board milling machines are increasing crew productivity and trimming construction schedules, according to AWCI member contractors.
- Prefabrication is a huge driver of technology adoption, according to AWCI member contractors.
- Huge benefits would accrue to AWCI member contractors using 3D modeling and integrated software technologies if the entire AEC value chain could standardize the specification of common wall and ceiling types, according to the author.

Questions to ask yourself

- What problems do we have that technology can solve?
- What is needed to do our work better?
- Are employees excited about a new technology, and are they willing to learn how to use it?
- What is the return on invested capital for a proposed technology acquisition?
- Why are we considering purchasing this technology—because it is "cool" or because others recommend it for us?

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APPENDIX 1
GLOSSARY

3D Printing. A form of additive manufacturing used in construction to create building components and structures. Benefits include material savings and productivity gains.

Artificial Intelligence (AI). A broad field of science concerned with programming computers to do tasks that normally require the input of human intelligence.

Asset Management. Technology that uses tags, readers and sometimes IoT devices to identify and track construction tools, equipment and materials.

Augmented Reality (AR) Layout Systems. Visualization hardware and software technologies that enable a constructor to see a 3D digital plan projected in real time onto surfaces where he can lay down framing components using only the digital inputs provided by his AR headset.

Blockchain. A shared ledger, which is used to store, encrypt and protect data.

Building Information Modeling or Model (BIM). A digital representation of physical and functional characteristics of a facility and a shared knowledge resource for the entire lifecycle of that facility. BIM also refers broadly to the creation and use of digital models and the collaborative processes between project stakeholders using those models.

Cloud Computing. On-demand delivery of computing power, database storage, applications and other IT resources via the Internet.

Data Analytics. A range of techniques and tools for the acquisition and transformation of raw data into information to predict future outcomes.

Digitalization. The use of digital technologies and digitized data to impact how work gets done and how construction stakeholders engage and interact. Digitization, a slightly different term, refers to converting paper documents to digital formats.

Drones. Autonomous flying machines that record images and videos so that construction companies can track, map, survey, inspect, verify and manage worksites. Also called unmanned aerial vehicles (UAVs).

Enterprise Resource Planning (ERP). A software solution that combines business functions into a single software package or platform, enabling the autonomous integration of data among different departments, such as accounting, project management, risk management and more.

Exoskeletons. A form of wearable human augmentation that can help reduce strain and fatigue for users and enhance their physical capacity.

GPS Trackers. Devices, usually in the form of PPE wearables, that combine sensors, GPS location technology and alert systems to track worker movements and activities in real time. Most trackers are integrated with alert systems to help workers avoid potential job-site hazards or to remind them of safety protocols.

Internet of Things (IoT). Integration of connected software and data-gathering software into physical devices to allow exchange of data.

Machine Learning. A subset of artificial intelligence that deals with writing algorithms to allow computers to "learn" from data.

Means and Methods of Construction. A term that describes the day-to-day activities a contractor employs to erect a structure in accordance with the designers' specification and performance requirements. The means and methods may require some incidental design, value engineering and minor modifications of plans to solve on-the-spot difficulties, and it may also make use of technology to improve the production schedule and installation quality.

Photogrammetry. The process of taking overlapping photographs of an object or space to create accurate 2D and 3D point clouds. Photogrammetry achieves the same level of accuracy of traditional digital scanning but with fewer data points.

Point Cloud. A set of X, Y and Z coordinates that represent a 3D shape generally produced by 3D scanners or by photogrammetry software. Point clouds are used to create 3D digital models of structures for design and construction planning and other applications.

Reality Capture. Use of laser scanners, mapping software and a mobile cart or drone to create point clouds of construction sites and capture 3D as-built data. Also known as high-definition surveying and 3D laser scanning.

Technology Stack. A compilation of software applications that separately address several business functions, such

as accounting, project management, estimating, quantity takeoff, time tracking, fleet management, collaboration, customer relationship management and more.

Total Stations. Surveying tools used in wall and ceiling construction for laying out interior framing and ceiling grid, useful especially on large projects or projects with curves, arcs, complex shapes or 3D ceiling clouds.

Virtual Reality (VR) Training. Software and special sensory headsets that create environments and scenarios to provide fully immersive, realistic and interactive training.

APPENDIX 2 INFORMATION RESOURCES

FMI
fminet.com

McKinsey & Company
mckinsey.com

National Institute of Building Sciences
nibs.org/page/informationresources

The ConTech Crew Podcast
jbknowledge.com/thecontechcrew

U.S. Chamber of Commerce Commercial Construction Index
uschamber.com

APPENDIX 3 CASE STUDIES

Case Study 1: Digital Field Management

California Drywall Company uses digital documentation management to improve the field productivity of its crews. Three software options are vital in this process.

PlanGrid is document management and collaboration software that enables the company's field office and field build team to communicate on drawings, RFI's, submittals and more. Documents and drawings are pushed to and from PlanGrid, which also updates the company's project management system.

Bluebeam Revu, another document management and collaboration tool, helps crews communicate with the field office about drawings, RFI's, submittals and more. BlueBeam Studio, a real-time collaboration tool, helps the field team "walk" a building, mark up the documents and hold virtual meetings.

Procore is a cloud-based construction management software platform that helps California Drywall manage people, materials, change-requests and more. GCs set up Procore for a project and make access to the project files available through the platform.

These digital tools enable field crews to clarify specifications and get approvals for minor changes without losing time.

Project managers can also work virtually, "walking" a job site or a floor with all drawings, reflected ceiling plans and elevations available in digital format. They can review progress with field personnel through virtual meetings and discuss schedules with the general contractor remotely.

"We are pretty much paperless," says Jaime Garcia, executive vice president at California Drywall. "Our time cards are on the iPad. Our safety walks and reports are on the iPad. Accident reports are on the iPad. If I want to order material, it's on the iPad."

Case Study 2: Going Paperless

Cameron Wies, estimator and lead technologist at T.J. Wies Contracting, Inc. in Missouri, is leading a team to convert his company's reporting processes to a paperless system.

The goal is to give lead men, foremen and project managers actionable information as quickly as possible.

"If I can offset the course of one bad project, then the technology pays for itself for about a whole year," Wies says.

Recently, T.J. Wies Contracting began using a PDF annotator called GoFormz to digitize documents, create reports and send notifications automatically throughout the company. Project managers can see extra work-order tickets and potential roadblocks as soon as the reports are created in the field.

Phase II of the company's digital document management transformation involves moving to a ERP system, which will integrate multiple software functions—project management, accounting, estimating and field documentation—onto a single platform.

Crew foreman will be able to report, say, an extra work order, and their change in the field will simultaneously auto-populate all ERP software modules, including finance, purchasing and project management. No one will re-enter or retype the work-order.

"We're cutting down the amount of times we have to enter the same information," Wies says.

Case Study 3: Financial Software Upgrade

In January 2020, Ironwood Commercial Builders, Inc., in California, switched to a new accounting and project management software after the previous software had become problematic.

"We would generate two different reports that should have had the same numbers, but they would have different numbers," says Nancy Brinkerhoff, president and CEO of Ironwood Commercial Builders in Northern California and 2019–2020 president of AWCI. "We didn't trust the software."

Brinkerhoff spent three months researching the switch to an accounting, project management and payroll solution from Foundation Software. Foundation was recommended by the company's CPA.

"We can actually run a Work in Progress on this one," Brinkerhoff says. "The other software didn't have a WIP report. It didn't even have a place to build a budget."

Brinkerhoff says the new, subscription-based software

costs $1,200 a month—considerably less than the former software's $60,000 upfront charge, $25,000 annual fee and time-sheet surcharges.

The person who had been dealing with the previous software now spends that time with project engineering. "The productivity has been great," Brinkerhoff says. "The payroll is much more streamlined. My payroll person has to work only 32 hours a week."

Foundation Publications

Available for download at www.awci.org/foundation/research.

Prefabrication in the Wall and Ceiling Industry: Trends, Strategies, Outlook and Recommendations

LEED® v4: Redefining Design, Transforming Contractors

Recession-Proofing Your Company: Lessons Learned from Past Recessions

Immigration: A Solution to Workforce Shortages

Lean Construction Practices for Contractors: Current Thoughts and Methodologies

Ownership Transition for Contractors: Current Thoughts and Methodologies

Attracting Young People Into Construction Field Positions

Navigating Uncharted Waters: Understanding Energy Codes and How They Impact the Role of the Contractor

Cost of Cold-formed Steel Products—Mines to Job Site

Creating an Injury Free Work Force

Building Information Modeling: Understanding and Operating in a New Paradigm

Green Building: Understanding, Bidding and Building Green

Immigration and Construction

Preparing for Tomorrow

Using Labor Brokers: The Legal Issues

Job Descriptions

Mold Litigation: Prevention and Defense

Preventing Losses from Moisture and Mold During Construction

Mold: Cause, Effect and Response

AWCI CARES (Caring Action Relief (in) Emergency Situations) is a financial assistance program of the Foundation of the Wall and Ceiling Industry to help the employees and families of the Association of the Wall and Ceiling Industry (AWCI) member companies who have experienced a major illness, accident or hardship beyond their insurance and financial capabilities.

If you know of someone who may qualify for an AWCI CARES grant, an application form is available on the AWCI website at www.awci.org/foundation.

AWCI CARES

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