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Jennifer Hess[a]; Marc Weinstein[b]; Laura Welch[c]
[a] Labor Education and Research Center, University of Oregon, Eugene, Oregon [b] Florida International University, Miami, Florida [c] Center for Construction Research and Training, Washington, D.C.

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Ergonomic Best Practices in Masonry: Regional Differences, Benefits, Barriers, and Recommendations for Dissemination

Jennifer Hess,[1] Marc Weinstein,[2] and Laura Welch[3]

[1]Labor Education and Research Center, University of Oregon, Eugene, Oregon
[2]Florida International University, Miami, Florida
[3]Center for Construction Research and Training, Washington, D.C.

Within construction the masonry trade has particularly high rates of musculoskeletal disorders (MSDs). A NIOSH-sponsored meeting of masonry stakeholders explored current and potential "Best Practices" for reducing MSDs in masonry and identified potential regional differences in use of practices. To verify and better understand the regional effects and other factors associated with differences in practice use, a national telephone survey of masonry contractors was conducted. The United States was divided into four regions for evaluation: Northeast, Southeast, Midwest, and West Coast. Nine practices with the potential to reduce MSDs in masonry workers were evaluated. Masonry contractors, owners, and foremen completed 183 surveys. The results verify regional differences in use of best practices in masonry. Half-weight cement bags and autoclave aerated concrete were rarely used anywhere, while lightweight block and mortar silos appear to be diffusing across the country. The Northeast uses significantly fewer best practices than other regions. This article examines reasons for regional differences in masonry best practice, and findings provide insight into use and barriers to adoption that can be used by safety managers, researchers, and other safety advocates to more effectively disseminate ergonomic solutions across the masonry industry.

Keywords construction, diffusion, ergonomics, injury prevention, masonry, musculoskeletal disorders

Address correspondence to Jennifer Hess, Labor Education and Research Center, 1289 University of Oregon, Eugene, OR 97403; e-mail: jhessdc@gmail.com.

INTRODUCTION

Construction workers are at significant risk of musculoskeletal disorders (MSDs), with incident rates in 2006–2007 of 41.4 (per 10,000 workers) compared with 35.4 for all industries.[1] Among construction workers, bricklayers have particularly high rates of injuries, ranking first among construction trades for back injuries with time away from work.[2] Mason tenders, laborers who supply bricklayers with work materials such as brick, block, and mortar and, in some areas, erect scaffolding, rank highest for MSDs resulting from overexertion.[2]

The physically demanding nature of the work, including awkward and static postures, explains why strains and sprains are the most common type of work-related injury in construction. Some of the risk factors identified for back injuries among masonry workers are block weight; frequency of lifting; height from which brick, block, and mortar are lifted and then placed; distance of the work from the worker; and high expected production rates.[3]

It is not uncommon for bricklayers to lay 200 blocks or 600 bricks per day. If a bricklayers handles 200 concrete masonry unit (CMU) blocks (measuring 0.2 × 0.2 × 0.4 m) weighing 17.2 kg each, he will lift over 3440 kg in an 8-hr workday, while those laying 600 bricks weighing 5 lb (2.27 kg) each per day handle up to 1361 kg per day. Combined with repetitively lifting heavy weight, bricklayers bend their back more than 60° 3–4 times a minute for over 4 hr per day.[4] This combination of high forces, awkward postures, and repetition places bricklayers at high risk for MSDs. Mason tenders, in addition to moving brick and block, repeatedly lift, carry, and empty 43.1-kg bags of mortar and shovel mortar, and keep the bricklayer supplied with mortar.

The Center for Construction Research and Training (CPWR) has worked with the masonry industry to

(1) explore the use of existing practices,
(2) evaluate promising new practices, and
(3) develop programs to disseminate "Best Practices in Masonry."

As part of this effort, the National Institute for Occupational Safety and Health (NIOSH) organized a meeting of masonry stakeholders in Cincinnati, Ohio, in 2004.[3] This 2-day meeting brought together 43 people, including masonry contractors, workers, occupational health and safety specialists, researchers, contractor association representatives, ergonomics consultants, and representatives of state workers' compensation programs. During the meeting the NIOSH work

group identified a list "Best Practices," which consisted of ergonomic equipment, materials, and work practices that the group believed would reduce the risk of work-related MSDs, based on currently available research findings.

Among focus group participants there was no serious disagreement regarding the factors creating the greatest risks for bricklayers and mason tenders. However, they did identify the existence of regional differences in the use of equipment, materials, and work practices. If independently verified, these regional differences could provide insights as to how to best disseminate ergonomic best practices in masonry.

In contrast to fixed industries, construction work in the United States is decentralized, with most work performed by small subcontractors. Therefore, work norms, defined as typical or common work practices within a group, and information flow could lead to localized expertise that is slow to diffuse nationally. Research into the diffusion of best practices[5,6] suggests that the level of penetration of a particular practice is important when crafting communication strategies to promote increased utilization of best practices.

This article presents the results of a national survey of masonry contractors to quantify regional differences in best practice utilization and explore potential barriers to adoption of these practices. This information will help researchers and safety advocates craft targeted strategies that will enhance adoption of best practices that reduce the risk of work-related MSDs.

METHODS

Telephone Survey

To measure the level and pattern of utilization of different equipment, material, and work practices in masonry, we developed and piloted a telephone survey to be administered to masonry contractors. In addition to providing data on the size of their company, information was collected pertaining to percentage of work done in commercial and residential construction, and union status. We elicited information about nine practices:

(1) Mortar Silos. Silos are designed to deliver mixed or pre-blended mortar to the work site using 1361-kg bags of mortar, reducing the need for mason tenders to manually handle 43.1-kg bags of mix and freeing them for other tasks.
(2) Grout Delivery Systems. These gravity feed systems deliver grout to walls rather than using buckets or pumps. This eliminates repetitively lifting and emptying heavy bags of grout into mixers.
(3) Mechanical Scaffolding. These systems include adjustable tower scaffolding and mast climbing scaffolding that allows work height to be readily modified using either a hand crank or hydraulics. These types of scaffolds raise and lower easily, eliminating the need to repeatedly rework platform height, allowing work to be kept between the knees and shoulders, a range that has been demonstrated to reduce physical stress and risk of injury to the low back and shoulders.[7–9]
(4) Half-Weight Cement Bags. Twenty-one-kg bags of cement reduce the load lifted and handled by mason tenders. Most venders can supply half-weight bags on request.
(5) H-Block and A-Block. H-block is CMU molded without the two ends, making it "open ended" and giving it the appearance of the letter H, while A-block is CMU molded without one end. These alternative block types allow bricklayers to place CMU block around rebar, pipes, and other vertical obstructions rather than lifting block over obstructions. There is an association between working with hands above shoulder level and neck and shoulder pain in construction workers.[8]
(6) Lightweight Block (LWB). LWB is made with aggregates that make it more porous and therefore lighter than standard medium weight CMU, though it meets the same structural standards as medium weight block. While block weights vary depending on the aggregate, LWB usually weighs about 12.7 kg compared with 15–17.2 kg for medium weight CMU. Several studies suggest a reduction in physical stress, workload, and health risks in masons working with lighter weight brick and block.[10–12]
(7) Autoclaved Aerated Concrete (AAC). AAC is another lightweight building material that has been used in Europe for over 60 years and is manufactured in several locations in the United States. Its lighter weight and the different method of handling AAC result in decreased shoulder stress.[13] It comes in many sizes, including 15.2 cm × 30.5 cm × 61.0 cm for non-load-bearing walls, to 20.3 cm × 30.5 cm × 61.0 cm and 30.5 cm × 30.5 cm × 61.0 cm block, and "jumbo block" that is craned in place for the construction of load-bearing walls. The 20.3 cm × 30.5 cm × 61.0 cm AAC block weighs about 15 kg but is 20.3 cm longer than CMU. As a result a bricklayer using AAC would handle one-third fewer blocks. It is assembled using a Thinset adhesive rather than mortar, hence, it requires less spreading or "buttering" by the bricklayer.
(8) Half-Size Pallets. On request, CMU can be ordered on pallets with half as many blocks. These "half-size pallets" are lighter and easier to handle and set on scaffolding using lifts. Lighter pallets can be placed closer to the job, reducing material handling by workers, a known risk for strains and sprains. The use of half-size pallets may create greater efficiency, since materials are more readily available to workers.
(9) Two-Person Lift Teams. When working with 30-cm CMU, some contractors and union contracts require two-person lifts. One study found low back compressive forces were significantly less in bricklayers lifting block in teams.[14]

We also gathered data from respondents on perceived advantages and disadvantages of the practices,

TABLE I. Telephone Survey Respondents by Region

	West Coast (n = 53)	Midwest (n = 45)	Southeast (n = 38)	Northeast (n = 47)	Total (n = 183)
>50% Commercial	81.1%	63.6%	71.1%	61.7%	69.8%
Hire Mostly Union	48.0%	48.8%	8.3%	36.4%	37.0%
1–10 Employees	79.2%	77.3%	68.4%	70.2%	74.2%
11–25 Employees	13.2%	18.2%	28.9%	21.3%	19.8%
25+ Employees	7.5%	4.5%	2.6%	8.5%	6.0%

and material/equipment availability. While few studies have examined the effects of these practices on total construction time, there is some evidence suggesting that ergonomic improvements increase bricklayers productivity.[7] Therefore, we asked contractors about productivity and time savings for each practice.

To develop the survey we collaborated with academic investigators familiar with construction ergonomics to decide on content. We gathered and incorporated input from four masonry contractors randomly drawn from our master list of contractors to refine the content. The survey was piloted with 23 masonry contractors randomly drawn from our list to ensure that questions were appropriate and understandable. Five to six questions were asked for each best practice:

(1) whether they used the practice,
(2) frequency of use,
(3) availability to trial,
(4) advantages, and
(5) disadvantages.

Study Sample

To verify and understand regional patterns of variation, the study focused on 16 states divided into four regions:

- Northeast (NE): Connecticut, Massachusetts, New York
- Southeast (SE): North Carolina, South Carolina, Florida, Georgia
- Midwest (MW): Minnesota, Wisconsin, Iowa, Texas
- West Coast (WC): Washington, Oregon, California, Arizona

Since masonry construction in the United States is highly decentralized and is performed by a large number of small enterprises, the research team compiled a list of 3400 masonry contractors from the Masonry Contractors Association of America (MCAA), Associated General Contractors of America (AGC), the Masonry Institute of America, the Building Trades Directory, The Blue Book, General Building Contractors of NY, and Masonry for Life (Arizona Masonry Guild). This master list was divided into four regional lists. Within each regional list, the order of the contractors was randomized, and research assistants proceeded to call contractors until data were received on approximately 50 contractors in each of the four regions. The researcher spoke with owners or managers in 236 companies working with brick, block, or stone where 203 agreed to participate (86% response rate). Since the list contained the names of inoperative telephone numbers of presumably defunct companies, we cannot definitively state the total number of contractors called.

Data Analysis

To examine the relationship between contractor attributes and the use of a given practice, we used logistic regression to model the use of a practice as a function of region, unionization, firm size, and industry sector and present them in Table III. For each equation a specific practice is a dichotomous dependent variable where "1" indicates the respondent reported "always" or "usually" using a specific practice, and "0" indicates infrequent or no use of the practice. In these same analyses, small firms (1–10 employees) are the referent group for firm size and were compared with medium (11–25 employees) and large (more than 25 employees) contractors. For the industry sector, coefficient estimates are provided for commercial contractors and are compared with residential contractors that make up the referent group. Union contractors are compared with non-union contractors, which is the referent group. To assess regional variation, one or two regions serve as the referent group in modeling each practice and can be compared with regions for which coefficients are presented. For each coefficient that is statically different from its respective referent group ($p < .05$), odds ratios associated with 95% confidence intervals of the odds ratios are also provided in Table III.

RESULTS

One hundred and eighty-three valid surveys were completed: 53 in WC, 45 in MW, 38 in SE, and 47 in NE. Forty-two percent of the surveys were completed by owners, while contractors, foremen, and other individuals completed the remainder. Table I presents data on the attributes of respondents, including whether 50% or more of their work was in the commercial sector, unionization, and size by region. Table II provides the frequency that masonry contractors reported "usually" or "always" using practices within each region.

TABLE II. Masonry Practice Use by Region

Practice	WC	MW	SE	NE	Total
Used on most/all jobs	%	%	%	%	%
Equipment					
Mortar silo (n = 180)	35.8	31.1	37.8	4.4	27.2
Grout delivery systems (n = 156)	4.0	26.3	39.4	0	16.0
Adjustable scaffolding (n = 180)	26.4	35.6	23.7	14.0	25.1
Materials					
Light weight block (n = 179)	40.4	36.4	47.4	22.2	36.3
H-block (n = 180)	37.7	11.4	10.5	11.1	18.9
AAC (n = 181)	1.9	2.3	2.6	0	1.7
Work Practices					
Half-size pallets (n = 175)	1.9	7.1	13.9	20.0	10.3
Half-weight cement bags (n = 178)	3.8	4.7	0	0	2.2
Two-person lift for 12-inch block (n = 175)	18.0	35.7	13.2	28.9	24.0

Regional Differences

Results confirm distinct regional differences in the utilization of practices identified by contractors in the NIOSH-sponsored focus group, with no single region standing apart as using an overall greater number of practices. For instance, in the NE region had lower utilization of mortar silos, but higher utilization of half-size pallets with a rate of 20% compared with 1.9% in the WC and 7.1% in the MW. Conversely, the WC had the highest utilization of mortar silos, 35.8%, and the highest level utilization of H-blocks, 37.7%.

TABLE III. Logistic Regression Analysis of Best Practices Used (Coefficient Estimates, Odds Ratios, and 95% CIs)

	Equipment			Materials			Work Practices		
	Mortar Silo	Grout Delivery Systems	MCS or ATS Scaffolding	H-Block	AAC Block	Light wt Block	Half-wt Cement Bags	Half-Size Pallets	Two-Person Lift Teams
West Coast	2.42** 11.3 (2.2–54.8)	—	0.65	—	7.46	0.57	9.01	—	–0.70
Southeast	2.53** 12.6 (2.4–65.2)	4.10*** 60.0 (6.5–553.4)	0.99	0.136 0.03–0.60)	7.64	1.26* 3.51	—	2.11	–0.62
Midwest	2.27** 9.7 (1.9–48.4)	3.48*** 32.5 (3.8–277.3)	1.30* 3.7 (1.1–12.0)	–1.58** 0.21 (0.06–0.68)	7.48	0.48	8.32	1.36	0.38
Northeast	—	—	—	–1.44* 0.24 (0.08–0.73)	—	—	—	2.37* 10.7 (1.2–91.7)	—
Union	0.16	–0.08	0.83	–0.37	–0.12	0.31	0.97	0.23	0.90* 2.5 (1.0–5.8)
Commercial	0.86	8.83	2.18** 8.8 (1.9–40.1)	0.73	–0.46	1.25** 3.5 (1.5–8.2)	–0.99	0.22	0.01
Small Employer	–0.83	–0.30	–0.52	–0.22	–0.57	0.52	–0.69	–0.78	–0.57
N	169	147	169	171	171	171	169	167	167
Model Chi^2	27.41	50.31	30.88	17.88	2.10	18.21	5.04	11.80	16.23

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

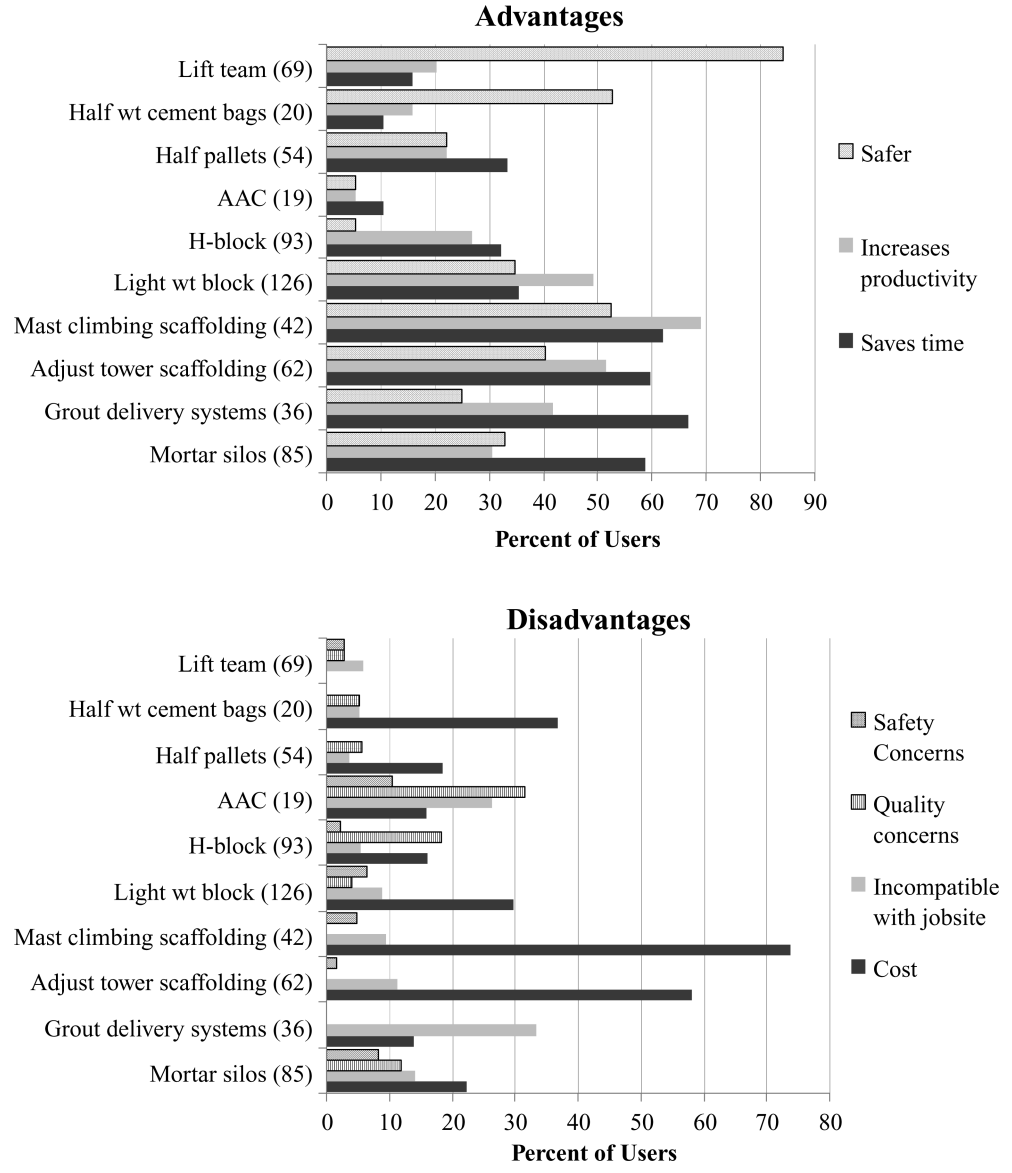

FIGURE 1. Best practice advantages and disadvantages reported by masonry contractors (numbers of respondents to each question in parentheses).

Perceived Advantages and Disadvantages of Best Practices

This survey asked respondents about "advantages" and "disadvantages" because feedback from contractors suggested these were terms they more readily used. In our experience, "advantages" are "benefits" and lead to adoption of a practice, while "disadvantages" are "barriers" to adoption. Figure 1 provides a summary of responses by contractors who reported using a practice "sometimes," "frequently," or "always" when asked about specific advantages ("saves time," "enhances productivity," and "safer") and disadvantages ("cost," "safety concerns," "compatible with jobsite," and "quality concerns"). Percentages are provided for ease of interpreting the data; however, the number of respondents answering questions ranged from 19 to 126.

For most practices the greatest advantage was time savings, followed closely by increases in productivity. Increasing safety usually ranked third, except for the use of half-weight cement bags and two-person lift teams with 30-cm block, where safety was the most important advantage. Cost was the greatest disadvantage for equipment, such as mast climbing scaffolding and mortar silos, while quality concerns were the greatest disadvantage for H-block and AAC. Concern about maintenance was a disadvantage for mortar silos (nine respondents), grout delivery systems (five respondents), and mast climbing scaffolding (seven respondents). There were

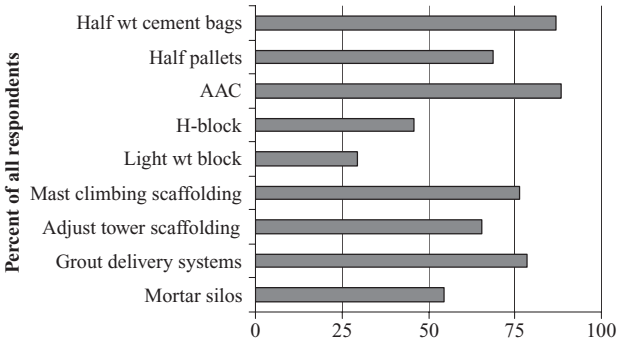

FIGURE 2. Availability of best practices to trial in contractor area.

a substantial number of "other" responses for each practice, which are provided in the Discussion section. Figure 2 demonstrates that with the exception of LWB, perception was that most practices were available in their area to try. In the multivariate analysis in Table III, a number of statistically significant relationships are apparent among practices across the four regions; associated odds ratios for the significant variables are provided in brackets.

Equipment Utilization

In the case of mortar silos, their relatively low utilization in the NE region compared with the other three regions was statistically significant ($p < 0.01$), after controlling for company size, unionization, and sector. Grout delivery system utilization was higher ($p < 0.001$) among contractors in the SE and MW regions than in the WC and NE regions. Mechanical mast climbing scaffolding or adjustable tower scaffolding was used more in the MW ($p < 0$ .05) than in the other regions. In addition, commercial contractors reported higher utilization of adjustable tower scaffolding than residential contractors ($p < 0.01$). Whereas respondents in the NE reported lower utilization of mortar silos and adjustable tower scaffolding, respondents in this region used reduced-size pallets more frequently ($p < 0.01$) than contractors in the other three regions surveyed.

Materials Utilization

Significant differences in the utilization of lightweight block were also found, with the SE region having higher utilization ($p < 0.05$) than the other three regions surveyed. Commercial contractors also had greater utilization ($p < 0.01$) of lightweight block than residential contractors. In the case of H-block, the multivariate analysis confirmed the findings in Table II, that the use of H-block is higher in the WC region than in the MW, SE, and NE regions. While the sample was too small for a statistical comparison among states, in the WC region we found that 54% of contractors surveyed in California used H-block compared with 29% in Washington and Oregon. Utilization rates of AAC block were low in all four regions, and its overall low utilization was not associated with any of the independent variables.

Work Practices

Use of half-weight cement bags was low in all four regions, and utilization rates were not associated with any of the independent variables in the region. Half-size pallet use was low, although use was higher in the NE ($p < 0.05$) than in the other three regions. Regional differences in the use of two-person lifts were not found to be statistically significant, but there was a significant correlation ($p < 0.05$) between union status and the use of two-person lift teams for 30.5-cm blocks.

DISCUSSION

These findings demonstrate that masonry contractors are beginning to use new equipment, materials, and work practices that provide ergonomic advantages. In discussing the logistical regression analysis results, we include qualitative responses from survey respondents, insights from our field research, and in Table IV, we note suggestions for dissemination efforts and areas where additional data may further explain differences.

Equipment

Mortar Silos

While contractors in the NE cited cost as an impediment to the use of mortar silos, this was not the case in the other three regions. The most commonly cited "other" advantages of mortar silos were improved consistency and quality of the mix, labor savings, and cleaner. These aspects of mortar silos should be part of future dissemination efforts. The main disadvantage was batch size because using a mortar mixer on small jobs is not feasible.

Grout Delivery Systems

In the MW and SE the most commonly cited advantage was enhanced productivity. These systems may not be appropriate for use in the WC region due to the more rigorous seismic building codes in this region. Other advantages of using grout delivery systems noted by contractors were "saves wear and tear on the back" and they were "timelier to use." Grout delivery systems were used infrequently in the NE where contractors felt they were incompatible with jobsites. Types of incompatibility noted included the need for forklift access, inability to use these systems on interior walls, space limitations, and concerns about concrete hardening in the hose. In the NE about half the contactors surveyed reported that grout delivery systems were not available to try in their area.

Adjustable Scaffolding

One-quarter to one-third of all respondents in the WC, MW, and SE reported using either hydraulic mast climbing scaffolding or adjustable tower scaffolding. However, only 14% reported used it on a regular basis. The main advantages

TABLE IV. Summary of Survey Findings, Recommendations, and Future Research Needs

Practice	Main Findings	Areas for Further Research	Dissemination Recommendations
Mortar silos	• Very low use in NE • Utilization rates in other regions moderate	• Further investigation needed into whether site characteristics or cost of equipment explain observed lower utilization in NE	• Promote in NE region • Emphasize cost/benefit and productivity increases
Grout delivery systems	• Significantly lower utilization in WC and NE	• Confirm whether air pockets are a problem for meeting stringent WC seismic codes • Confirm whether site constraints in NE account for lower use	• Verify availability and educate contractors about availability and benefits
Adjustable scaffolding	• Very low utilization in NE • Concerns related to training of workers and setup time	• Investigate whether site constraints in NE account for lower utilization • Investigate training gaps and related safety issues with set up and breakdown	• Key is to emphasize increases in productivity that offset capital investments • Becoming industry standard for large construction companies
H-block	• Moderate utilization on WC, especially CA with strict seismic codes • Low use in NE, MW, and SE	• Investigate relationship between frequency of rebar and productivity to determine where productivity offsets higher cost	• Promote labor savings associated with use, especially when frequent vertical rebar specified • Address quality perceptions
Lightweight block	• Moderate utilization in WC, MW, and SE some of the time • Use frequency could increase	• Examine extent to which local supply of lightweight aggregates could be increased	• Promote labor savings and reducing MSDs • Greater use of light pumice type LWB for internal walls • Address availability perceptions
AAC	• Low utilization in all regions • Lack of familiarity introduces uncertainty about using • Low demand means low availability	• Examine physical benefit to workers for reducing MSD risk • Clarify ability of AAC to meet local building codes	• Promote “green attributes” of AAC • Provide information clarifying AAC code requirements
Half-weight cement bags	• Low utilization in all regions • Increased use of grout delivery systems may offset demand/need	• Investigation needed into regional availability and relative cost	• Promote improvements in productivity and reductions in manual handling • Educate contractors about availability • Address ability to specify pallet size
Half-size pallets	• Low utilization in all regions	• Further investigation into regional availability and relative cost needed	• Promote improvements in productivity and reductions in manual handling • Educate contractors about availability and their ability to specify pallet size
Two-person lift teams	• Use appears to be related to union contract language/requirements	• Research needed to investigate risks associated with uneven loading on individuals, and working on uneven terrain	• Greater union specification of lift teams • Promote sparing backs and shoulders • Minimal or no negative impact on productivity

of using adjustable scaffolding cited were labor savings, ability to work at optimal height, and mobility. The main "other" disadvantages were setup time (they could be bulky and difficult to assemble and disassemble), they are impractical for small jobsites, and cost. Several contractors felt it took too much time to train workers to assemble the scaffolding, while others commented that with training, adjustable mechanical or hydraulic scaffolding can be rapidly assembled, allowing materials to be placed close to workers, as work height can be quickly changed, all of which result in enhanced productivity. One concern voiced by contractors in the Northwest was that the tall vertical "guide" components on adjustable tower and mast climbing scaffolding made covering them difficult during wet weather.

Materials

H-Block

Open-ended block such as H-block and A-block, was used almost four times more frequently on the WC than in other parts of the country. This likely relates to the more stringent seismic codes on the WC, but most particularly in California, which require placement of vertical rebar as frequently as every 20.3 cm. An emerging trend nationally is the need for enhanced structural reinforcement in response to potential terrorist threats, and extreme weather conditions, such as hurricanes. If rebar reinforcement becomes more prevalent, shoulder injuries in masons could increase unless open-ended block or other means such as high lift grouting are used to prevent excessive overhead lifting. Users of H-block stated that using H-block was faster, lighter, and "easier to handle" compared with knocking out the ends of CMU, and it saved labor.

The main disadvantages expressed about H-block were breakage of fins (sides) and blowout during grouting. However, contractors in California use open-ended block almost exclusively and reported few problems with block quality, breakage, or blowouts. The perception that H-block is substantially more fragile may relate more to resistance to changing work practices than to material quality problems. H-block is generally more expensive than standard block and requires solid wall grouting and building a larger footing for the additional wall weight. However, contractors who use H-block frequently suggest there are productivity gains, especially when there is frequent vertical rebar. Moreover, in California, due to economics of scale, H-block costs the same as other CMU.

Lightweight block

While LWB was used significantly more in the SE, it was also used extensively in the MW and WC. Pumice, perlite, and permiculite were used by one-third of the contractors surveyed, but expanded shale and fly ash were also frequently used. Some respondents stated that lack of availability of lightweight aggregates was one reason for not using LWB more frequently. However, manufacturers we contacted in each region indicated that aggregates were available, so this may reflect resistance to changing work practices more than an availability issue.

At the same time, LWB use ranged from 22% in the NE region to 47.4% in the SE region, suggesting broad use despite reported shortages of aggregates. Respondents overwhelmingly indicated that LWB was easier to handle, had better fire ratings, and resulted in labor savings. Several contractors noted "it's easier on the men, at the end of the day a mason can lay 250–350 regular block but 400–425 LWB." The main disadvantages cited were issues around moisture absorption and perceptions about material strength. In wet climates a waterproof covering is needed over LWB for exterior walls. However, many interior walls could be built with LWB, in particular, with lightweight pumice block, which weighs only 8.2 kg. Several contractors believed that LWB lacked compressive strength. However, LWB meets the same ASTM C90 code for load bearing and ASTM C129 code for non-load-bearing walls as medium weight CMU.

Autoclaved Aerated Concrete (AAC)

Our survey found very low utilization of AAC in all four U.S. regions. While AAC is a relatively new material in the United States, it has been used extensively in Europe for 60 years. In the United States many contractors know little about this emerging building material, while others suggest that shipping costs make its use prohibitive, since it is only manufactured at a few plants in the United States. One advantage of AAC frequently expressed by contractors who use it was better insulation, fire ratings, and soundproofing. Some contractors expressed concerns about the quality of AAC and its ability to meet local codes, though manufacturers indicate that it meets the same ASTM standards as CMU for structural integrity.

Work Practices

Half-Weight Cement Bags

Most contractors rely on mason tenders handling 43-kg bags of cement, even though NIOSH recommends that under optimal conditions 23 kg is the maximum weight a male can safely lift.[15] Our findings indicate that on average only 10.3% of contractors used half-weight bags of cement. These findings compare with a telephone survey by Salem et al.[16] that found only 17% of producers, suppliers, and contractors make, sell, or use half-weight cement bags. Respondents from that study suggested that barriers to use included low demand, higher cost, and shipping and handling difficulties. Another possible reason is that as contractors switch to the use of mortar silos, manual handling of cement becomes less necessary. Yet, mason tenders on small construction sites, where mortar mixers are impractical, could benefit from half-weight cement bags.

"Other" advantages noted by several contractors were that half-weight cement bags were lighter, easier to handle, and resulted in less "wear and tear" on workers. While few disadvantages were noted, the main disadvantage given for not using half-weight cement bags was that their use requires more trips by the mason tender, which takes more time. Other

respondents reported they thought half-weight cement bags were not available in their area.

Half-Size Pallets

Half-size pallets use was low across all four regions, though they were used significantly more in the NE than in other regions. Few disadvantages were given, though some respondents indicated that they "take up too much space" because there are more pallets, or were "inconvenient." However, they can be stacked as high as standard size pallets and should not require additional storage space. Two respondents indicated that they did not use half-size pallets because they were not specified, but this appears to be a misconception since choosing pallet size is within the domain of the masonry contractor.

Two-Person Lift Teams

The use of two-person lift teams when laying 30.5-cm block was significantly associated with unionized contractors, which most likely reflect contract language related to lifting. The main advantage for using lift teams reported by many contractors was that bricklayers lifted less weight resulting in "less wear and tear on workers," "less low back stress," and "less fatigue" by the end of the day. The most commonly cited disadvantage to using lift teams was worker compatibility and ability of workers to work in unison. Several contractors felt that workers needed to be similar in size and work speed to work as a team. Productivity when using lift teams is a controversial issue among contractors. Anecdotal evidence suggests that lift teams are more productive than bricklayers working alone, and some contractors report that bricklayers working in teams are less fatigued at the end of the day.

Regional Differences in Adoption

These findings confirm there is considerable variation in masonry construction practices in the four regions examined, and that except in the case of two-person lifts, safety was not the most important consideration in choosing equipment, materials, and work practices. This is notable because it suggests that in some regions of the country, best practices in terms of reduction of MSD risks would also appear to be cost-effective. In the long run, the market may be leading to efficient *and* safe practices displacing older practices. For example, this may be occurring with adjustable tower scaffolding and mortar silos.

However, in the short-term, markets can be inefficient, and when the safety of individuals is at stake we should consider how to spur the adoption of safe work practices. This is particularly important in the construction industry where decentralization and local work norms are important.[17] In contrast to large organizations that can learn and transfer best practices quickly, specialty contractors are typically micro-enterprises that operate in relatively limited geographic regions with little capital, in highly competitive markets.

Coupled with contractors frequently rising through the ranks and learning management informally, existing practices and norms tend to be strongly engrained, resulting in the slow diffusion of accurate information and creating a certain degree of aversion to the adoption of new practices. For example, the lack of information about the productivity gains in H-block, availability of half-sized pallets, or contractor ability to request a particular type of block or cement bag size could impede adoption in some parts of the United States. Similarly, dissemination efforts to reduce regulatory uncertainty regarding AAC, LWB, and H-block could lead to both greater demand and supply. Finally, the case of two-person lift teams indicates a clear relationship among the presence of organized labor, concern with work safety, and the adoption of safer work practices. In these instances there is a need for safety professionals to share experiences across regions and provide accurate information about best practices to contractors.

STUDY LIMITATIONS

The study has a number of important limitations. First, the cross-sectional design of the study provides only a snapshot of usage at a particular point in time and does not provide data as to whether the observed differences are stable or whether some practices are rapidly becoming more common. Related to this, the decentralized nature of the industry and the frequent creation and dissolution of small construction contractors create problems when assessing the representativeness of the sample. This may lead to uncertainty in assessing the true level of utilization of specific practices. Likewise self-report data on utilization of practices in the field could be problematic.

However, there is no indication that errors associated with sampling and measurement co-vary with the independent variables of interest. Finally, due to resource constraints the study could investigate practices in only 16 states, though the selection of states was based on input from a NIOSH focus group that included representation of masonry stakeholders from around the country.

CONCLUSION

These findings provide insight into the regional differences in utilization levels of ergonomic best practices within the masonry trade, and identify specific advantages, which enhance adoption, and disadvantages, which are barriers to adoption. In the past, construction dissemination efforts have tended to address the entire industry without taking into account regional differences caused by economics, building codes, and work norms that may create barriers to adoption in one area and not in another. The impact to the construction industry is improved worker safety by applying these findings to the development of more effective dissemination strategies that are tailored to individual practices and that address regional differences.

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