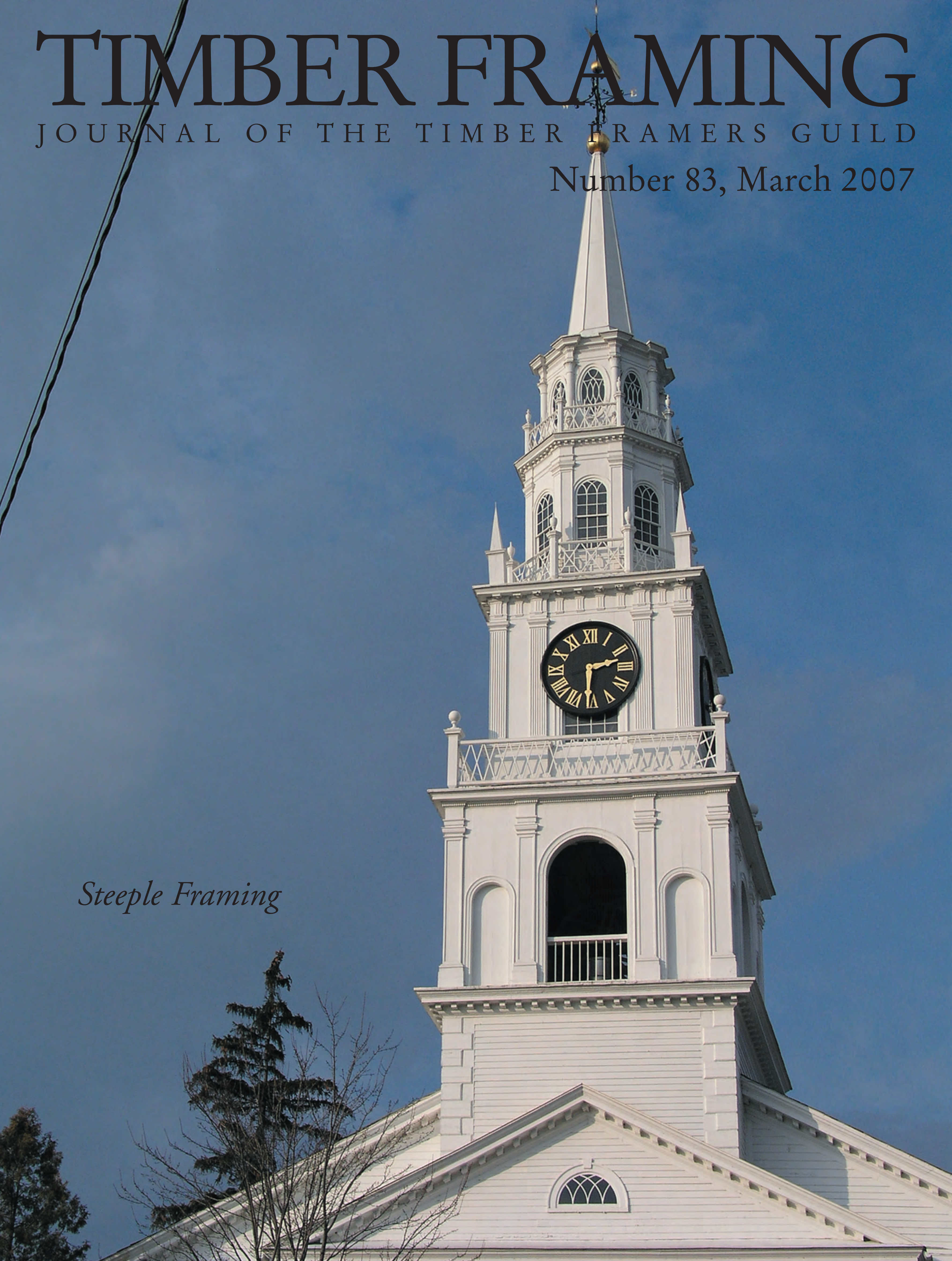
TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 83, March 2007



Steeple Framing

TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

NUMBER 83 MARCH 2007

CONTENTS

On the front cover, view of the Congregational Church, Middlebury, Vermont, built 1806–09, with a steeple height of 135 ft.

On the back cover, view of Middlebury's main street through an elliptical window of the second lantern of the steeple.

Photos by Ken Rower.

PO Box 60, Becket, MA 01223
888-453-0879 www.tfguild.org

Editorial Correspondence
PO Box 275, Newbury, VT 05051
802-866-5684 journal@tfguild.org

Editor Kenneth Rower

Contributing Editors
Guild Affairs Will Beemer, Joel C. McCarty
History Jack A. Sobon
Timber Frame Design Ed Levin

Published quarterly. Subscription $25 annually or by membership in the Guild (apply to Becket address above).

ISSN 1061-9860

TIMBER FRAMING, Journal of the Timber Framers Guild, appears in March, June, September and December. The journal is written by its readers and pays for interesting articles by experienced and novice writers alike.

1985

SAFE WORK PRACTICES

III. Personal Protective Equipment

Previous articles in this series (in TF 77 and 80), excerpted from the developing Guild curriculum, have addressed hazards in the timber framing shop and at the worksite. Once you have recognized these, you can design helpful improvements (guards, railings, etc.) and control work practices to minimize health and safety dangers. It's impossible to eliminate all hazards, however, and your next step is to identify those that remain and rely on personal protective equipment (PPE) to further protect you and your employees.

COWBOYS wear chaps. Blacksmiths wear leather aprons. Throughout history, people have used personal protective equipment (PPE) to guard them while they work. Today, as in the past, PPE can make you more productive as well as safer. In this article, we'll look at the types of equipment most suitable for timber framers, as well as at employer and employee responsibilities and Occupational Safety & Health Administration (OSHA) regulations.

Personal protective equipment comprises any device or garment worn by the worker as a last line of defense against jobsite hazards, and includes items used to protect the eyes, face, head, body, arms, hands, legs and feet. Examples are goggles, helmets, head covers, gloves, rubber slickers, disposable coveralls, safety shoes, protective shields and barriers. PPE devices alone should not be relied upon to provide protection against hazards. They should be used in conjunction with guards, controls and good construction and shop practices.

According to OSHA requirements (Standards 1910 and 1926), PPE must provide adequate protection against the particular hazards for which they are designed, be of safe design and construction for the work to be performed and reasonably comfortable when worn under the designated conditions, fit snugly and not unduly interfere with the movements of the wearer, be durable, cleanable and able to be disinfected and, finally, distinctly marked to facilitate identification of the manufacturer and standards met.

OSHA requires that many categories of PPE meet or be equivalent to standards developed by the American National Standards Institute (ANSI). ANSI has been preparing safety standards since the 1920s, when the first safety standard was approved to protect the heads and eyes of industrial workers. PPE manufactured or sold in Europe must have the designation "CE" (Conformité Européene) to show the equipment meets the equivalent European safety standards; the Canadian Standards Association uses the "CSA" mark.

Employers must make certain that any imported equipment procured meets these standards. Employees who provide their own PPE should make sure their equipment conforms to the employer's criteria, based on the hazard assessment, OSHA requirements and ANSI standards.

OSHA requires PPE to meet the following ANSI standards: Eye and Face Protection, ANSI Z87.1-1989 (USA Standard for Occupational and Educational Eye and Face Protection); Head Protection, ANSI Z89.1-1986; Foot Protection, ANSI Z41-1991.

Before looking at specific PPE, let's see what OSHA says the employers' and employees' responsibilities are. First, the employer is responsible for conducting a hazards assessment of the workplace to determine if there is a need for PPE. Such hazards might include flying debris (e.g., wood chips) striking one in the eye, falling objects (such as tools) striking one in the head, protruding objects that can be bumped into, saws and other equipment that can cut hands and arms, heavy loads (such as timbers) that can drop or roll onto feet; also notably heavy loads to lift, hazardous materials or fumes that irritate the lungs, mouth and skin, excessive machine noise, radiation such as from intense sunlight, laser beams or welding; and inclement weather for outdoor workers.

Sources for hazard assessment checklists can be found on the Web, and such an assessment must be documented in writing to meet the OSHA requirement. OSHA has an excellent resource for how to conduct an assessment at Standard 1910, Subpart I, Appendix B. For all PPE, your supervisor's requirements overrule your personal assessment of the risks. If the boss says, for example, that hardhats must always be worn on site, so be it, even if the hazard is not evident to you.

The bottom line here is that OSHA doesn't have blanket rules about what equipment is required until the hazards assessment is done. Your decision to use or not use certain PPE is based on the written assessment. If your assessment reveals that certain PPE is not required because there is no significant risk, you have a much better defense than having no assessment at all. But woe to you if an inspector drops by and there is no assessment done.

Once the risk has been identified, the employer must help the employee select the PPE appropriate for the job and then provide it at no cost to the employee. Employers should purchase high-quality, comfortable PPE since there will be less resistance to using it and it will last longer. Some exceptions apply when employees may have to purchase their own equipment, such as for prescription safety lenses or when equipment can be worn outside the workplace for other purposes (cold weather gear, for example).

The employer must approve personal equipment not purchased by the employer before it can be used. Once the equipment is purchased the employer is responsible for maintaining the equipment and training each employee in its proper use. This training must include when and what PPE is necessary and its limitations; how to put on, take off, adjust and wear PPE; and how to care for and store it. If a piece of PPE is damaged beyond repair, it must be discarded and replaced. Finally, the employer is required to keep a written record of the hazards assessment and employee training.

Employees, for their part, have the responsibility to wear and care for PPE properly and demonstrate their understanding of it, as well as to attend all training sessions. They must also read and follow all warnings and precautions that appear on tools, equipment, chemicals, Material Safety Data Sheets (MSDS), and personal protective equipment. They must listen to the directives of the supervisor or the company's safety director and report any and all unsafe conditions or defective equipment.

Now let's look at some specific PPE that might be appropriately used in timber framing.

HARDHATS AND HEAD PROTECTION. A head injury can impair you for life—or it can be fatal. Wearing a safety helmet or hardhat is one of the easiest ways to protect the head from injury

Fig. 1. Hardhats or safety helmets with or without brims are de rigueur at timber frame raisings. Chin straps are definitely useful. Note that stickers on hardhats must be of a compatible material and their numbers should be kept within reason to allow proper inspection of the hat.

Will Beemer

from impact and penetration as well as from electrical shock and burns. OSHA requires you to wear head protection whenever there is a danger of objects falling from above, such as when working below others who are using tools, or in the woods where a tree limb might fall, or working under a crane; whenever you might bump your head against fixed objects, such as exposed pipes or beams; or whenever there is a possibility of accidental head contact with electrical hazards.

Hardhats should be worn with the bill forward. However, brimless helmets have become increasingly popular at timber frame raisings. The brim (or bill) of a hardhat is designed to deflect falling objects, but it's more important for people climbing on a frame not to have a brim obstructing their view overhead. There is also a hazard of the brim bumping on a timber as one moves about the frame, thus knocking the hat off (Fig. 1).

In general, protective helmets or hardhats should resist penetration by objects, absorb the shock of a blow, be water resistant and slow burning and come with clear instructions explaining proper adjustment and replacement of the suspension and headband. Hardhats must have a hard outer shell and a shock-absorbing lining that incorporates a headband and straps that suspend the shell from 1 to 1¼ in. (2.54 cm to 3.18 cm) away from the head. This type of design provides shock absorption during an impact and ventilation during normal wear.

Types of Hardhats. Hardhats are divided into two types: Type 1 for impact and penetration resistance from the top, and Type 2, which offers this protection from the sides and back as well. There are also three industrial classes:

Class E (formerly Class A) hardhats provide impact and penetration resistance along with limited voltage protection (up to 2,200 volts).

Class G (formerly Class B) hardhats provide the highest level of protection against electrical hazards, with high-voltage shock and burn protection (up to 20,000 volts). They also provide protection from impact and penetration hazards by flying or falling objects.

Class C hardhats provide lightweight comfort and impact protection but offer no protection from electrical hazards.

Another class of protective headgear on the market, called a "bump hat," is designed for use in areas with low head clearance and recommended for areas where protection is needed from head bumps and lacerations. Bump hats are not designed to protect against falling or flying objects and are not ANSI approved. It's important for employers to check the type of hardhat employees are using to be sure it provides appropriate protection. Each hat should bear a label inside the shell that lists the manufacturer, the ANSI designation and the class of the hat.

Size and Care Considerations. Protective headgear must fit. Most protective headgear comes in a variety of sizes with adjustable headbands to ensure a proper fit (many adjust in ⅛-in. increments; ones with ratcheting knobs in the back are best). There should be sufficient clearance between the shell and the suspension system for ventilation and distribution of an impact. The hat should not bind, slip, fall off or irritate the skin. A comfortable, easy-to-adjust piece of PPE is more likely to be used.

Periodic cleaning and inspection will extend the useful life of protective headgear. An each-use inspection of the hardhat shell and suspension system for holes, cracks, tears or other damage is essential. Paints, paint thinners and some cleaning agents can weaken the shells of hardhats. Never drill holes in protective headgear. Labels and stickers may hide damaged areas. Never store cigarettes, tools or other items in the suspension system. Don't store protective headgear in concentrated sunlight or high heat (such as under the rear window of a car). Signs of deterioration include chalking or flaking.

Always replace a hardhat if it sustains an impact, even if damage is not noticeable, and retire any hat after ten years of service. Dispose of any retired PPE immediately so it can't be used. Renew suspension systems (available as replacement parts) when damaged or when excessive wear is noticed. It's not necessary to replace the entire hardhat when deterioration or tears of the suspension systems are noticed.

EYE AND FACE PROTECTION. Eye injuries are often permanent, and can be caused by objects striking the eye during operations such as grinding, hammering, sawing, chiseling, sanding and power-washing; contact with chemicals and other hazardous materials; being struck by swinging objects such as chains and ropes or falling objects such as tools; walking into objects; and by viewing radiant energy sources such as welding operations or lasers.

Safety glasses (spectacles) are intended to shield the wearer's eyes from impact hazards such as flying fragments, objects, large chips and particles. They are more resistant to impact and heat than regular glasses. Side shields can be attached when protection is needed from hazards not directly in front of the worker, and provide some additional protection from heat. Lens coatings with the correct filter shade can provide protection against radiation hazards.

Safety goggles provide additional protection from dust, heat and chemical hazards by sealing around the eyes, and are available in vented (for dust) and nonvented (for chemicals). They can also be used in conjunction with prescription glasses. Goggles should fit the face immediately surrounding the eyes and form a protective seal to prevent objects from entering under or around them.

Face shields are intended to protect the entire face, or portions thereof, from impact hazards such as flying objects and from heat, chemical splashes and liquid sprays, and can often be used with hardhats. They are especially appropriate for chainsaw work. Always use face shields in combination with safety spectacles or goggles for additional protection, as the former are not specifically designed to protect the eyes.

Contact lenses may not be worn with full-face respirators, and should be worn with caution in a construction environment. If the lenses get contaminated during a critical operation, such as installing rafters on a windy day, the discomfort could cause a dangerous distraction. Always keep a spare set of contacts or glasses handy in case you lose or damage one of your contacts on the job.

Keep eye and face protection equipment in good order and clean it regularly using mild soap and water or special wipes designed for that purpose. Storage should be in a cool, clean and dry environment. Again, all such face and eye protection should be considered backup safety measures and used in conjunction with such primary safety measures as tool guards and ventilation.

HEARING PROTECTION. Hearing loss because of excessive noise is cumulative over time and thus not so evident as other effects. It will obviously be more of a problem in the shop environment, with constant noise from power equipment, than on an outdoor worksite, but a very loud bang can be just as damaging as a lower level noise of longer duration. OSHA says that hearing protection must be worn where noise levels measure over 85 decibels for more than an 8-hour duration, or in case of an equivalent exposure, and an annual testing program of the environment and employees' hearing must be conducted if those levels are detectable. Generally, the louder the noise the shorter the exposure time before hearing protection is required. At 115 decibels only 15 minutes of exposure are allowed without protection. Most power equipment in a woodworking shop runs at over 100 decibels. While it is possible, and may be required, to test the workplace using audiometric equipment, it's a good idea to wear hearing protection routinely in high-noise areas or when using power saws, impact tools, air compressors and the like.

Hearing protection devices come in two basic types: earplugs and earmuffs. Earplugs can be of a single-use, disposable type (usually foam) or reusable (often PVC or rubber). Disposable plugs are self-forming and, when properly inserted, can work as well as preformed reusable plugs. The advantages of earplugs are that they are lightweight and small, comfortable in hot weather and can be used with other safety equipment.

The disadvantages are that earplugs can work loose and may need refitting. If reusable, they require cleaning after each use and a specific fitting procedure—usually reaching across the back of the head with the opposite hand and gently pulling the top of the ear up and back while inserting the plug. If using a foam plug, compress it by rolling it in your fingers, then insert it well into the ear canal; PVC plugs are to be rotated during insertion. Hold the plug in place for a few seconds to make sure it expands and seats properly.

Earmuffs are usually not so effective as earplugs because they require a tight seal around the ear. Earmuffs are easy for your employer to supervise, one size fits all and they fit better for long periods of time. But the disadvantages of earmuffs are that they are uncomfortable in a warm environment, press tightly against the ears, which can get painful over extended periods, and sometimes cause problems when used with other safety equipment.

Consider using earplugs if you wear glasses, earrings or have hair that would prevent the earmuffs from making a good seal. Store your hearing protectors in a clean, cool, dry place, clean them after each use and replace them when they become brittle or stiff.

GLOVES AND SKIN PROTECTION. The hazards assessment will determine what type of PPE is required (if any) to protect the hands and skin. Timber framing hazards might include slivers from timber, lumber and plywood, or frayed rigging and wire rope, as well as from harmful substances such as epoxy glues, treated lumber, oils and finishes. Workers with chainsaws are required to wear Kevlar chaps because of the extra hazards involved.

Leather gloves provide good protection when handling rough or heavy objects and rigging. Synthetic or fabric gloves provide slightly less cut- and abrasion-resistance but, with added coatings, may provide good slip-resistant qualities for securely gripping objects. Chemical- and liquid-resistant gloves should be worn when applying glues and finishes. Nitrile or neoprene gloves are generally the most suitable for working with these materials.

It must be noted here that emergencies should be part of your hazards assessment, and a complete first-aid kit will include latex or nitrile gloves to protect the hands from blood-borne pathogens.

Select gloves that fit snugly. Remove any rings that might cut or tear your gloves. Inspect your gloves before you use them. Look for holes and cracks that might leak, and don't hesitate to replace gloves that are worn or torn. After working with chemicals, hold your gloved hands under running water to rinse away any chemical residue or dirt before removing the gloves. Store gloves right side out where they can dry.

When working with powered rotating equipment, wear gloves only when the hazard from flying debris outweighs the hazard of the glove getting caught by the tool.

If the hazards assessment indicates risk of abrasion, bruises or cuts through the handling of timber or scrambling around on the frame, then the skin should be protected. Heavy cotton duck fabric found in clothing designed for construction works well.

Can I wear shorts on the job? Here's a good example of how utilizing workplace controls to reduce hazards can minimize the need for PPE: during a raising, if the use of a crane and a good scaffolding setup can minimize the hazards by reducing the need to handle timbers and climb on the frame, then the need for protective clothing is also minimized. Conversely, if workers are required to carry full belts of tools up on the frame, and those tools pose a hazard to the legs, then it's back to having heavy-duty long pants.

WET AND COLD WEATHER CLOTHING. Protective clothing is obviously the most important step in fighting the elements, by providing adequate layers of insulation. While personal requirements and preferences may vary widely, most of us should wear at least three layers of clothing: an outer layer (shell or coveralls) to shed rain, break the wind and allow some ventilation; a middle layer of wool or synthetic fabric to absorb sweat and retain insulation in a damp environment (down is a useful lightweight insulator but ineffective once wet); and a breathable inner layer of cotton (if the work is not strenuous), silk or synthetic weave to allow ventilation.

Pay special attention to protecting feet, hands, face and head. Body heat loss is proportional to the surface area exposed and, if the rest of you is well covered and insulated, the head represents a considerable amount of surface area. Hardhat liners are available to cover ears, cheeks and chin. Footgear and gloves should be insulated (or augmented by chemical warmers) to protect against cold and dampness. Glove liners can be useful, but it's tricky to be sure your gloves are sized properly. Gloves that are too small can restrict blood supply yet if too large can be caught by rigging or tools.

Here's something most of us haven't thought of: keep a change of clothing available in case work garments become wet. Avoid sweating by removing layers before heavy exertion, and, if they're damp, change undergarments (including socks) and gloves at breaks or lunch. Be sure to dry out your clothing overnight, especially boots with liners. Rubber boots with removable insulating liners are better in damp weather than leather, which loses its insulating ability when wet.

Although it's not a good idea to be working at all under such conditions, a piece of winter equipment that comes in handy on icy decks is a pair of slip-on mini-crampons with small studs to provide traction. Keep a pair in the truck for that early morning prep or unexpected ice storm (Fig. 2).

It's also good to have two pairs of shoes on site during wet weather, one for mucking around in the dirt and mud, and another for up on the frame. Obviously it's best to minimize trips up and down if this is the protocol.

An important factor to remember for any article of cold weather clothing is the wearer's freedom of movement. Don't wear insulated items so bulky that you have difficulty performing the tasks at hand, and avoid any headwear that obscures your vision. Sometimes the severity of the cold requires you to wear items that do limit your movements. The best advice for such times is to be extra cautious of your actions and fully aware of your surroundings.

SAFETY BOOTS AND FOOT PROTECTION. Workers at risk of foot injuries from falling or rolling objects or from crushing or penetrating materials should wear protective footwear. Timber framing hazards include dropped tools or timbers (and, in renovation work, perhaps protruding nails or spikes). Such hazards might differ between shop and building site, and thus the hazard assessment might dictate steel-toed shoes in the shop but not require them on site, or vice versa.

Since falling is normally a bigger threat during a raising than things falling on your foot, a "sticky" shoe is preferable, and often sneakers are the stickiest available (but avoid black soles that could mark the timbers). On a typical big job with a general contractor, however, sneakers may not be allowed and work boots required because the GC's hazard assessment blankets all of the trades. And, yes, you can get athletic-design and other specialized shoes with steel toes.

The type of foot and leg protection you use should depend on specific hazards, but the safety shoes must at least meet the ANSI Z41-1991 standards. Standard safety shoes or boots with slip-resistant soles, puncture-resistant shanks and compression-resistant toes should suffice for most hazards faced by timber framers.

RESPIRATORY PROTECTION. Air quality is one of the major areas where facility engineering and workplace controls can greatly reduce respiratory hazards through ventilation and exhaust systems or by containing the operation. Choosing to work with low-toxicity materials in the first place is always wise but not always practical. Unfortunately, all wood dust (some species more than others) is harmful to the lungs and breathing passages, and respirators may also be required to limit the harmful effects of finishes and glues. Dust and vapor are the prevalent hazards in the shop and each requires different types of respirators.

Selecting the Correct Respirator. The first step in selecting the correct respirator is to determine the level of hazard posed by the work environment. Four basic questions must be answered: What type of contaminant is present? What is its form? How toxic is it? What is its concentration?

You may not be able to answer all of these questions on your own. Work with a qualified supervisor or safety professional to determine the correct answers and become familiar with the respirator descriptions in PPE suppliers' catalogs.

In addition to determining the level of hazard posed by the environment, you must also consider how long you will be exposed to the contaminant, your individual sensitivity and your personal requirements. Do you wear glasses? Have a beard or other facial hair? Wear dentures? Will you have to wear other protective equipment?

There are two main types of respirators: air-purifying respirators (APRs) and supplied-air respirators (SARs). Most timber framers will want APRs, which include the disposable particulate types (dust masks) and half- or full-face respirators that take a variety of cartridges to filter the air when using solvents, glues, finishes and other vapor- and mist-producing hazards. Be aware that a dust mask is not sufficient PPE against most pressure-treated materials because the heat generated by cutting or drilling can produce harmful vapor as well as dust.

The array of respirators available can be dizzying and confusing (but not as bad as not wearing one). In general, check the label on the respirator to make sure that it clearly meets your requirements, whether it be for sanding wood or applying finishes. In the case of applying hazardous materials, check the product's Material Safety Data Sheet (MSDS), which will list not only the ingredients but also what PPE is required during use. Most timber framing shops will not generate the prolonged exposure to dust that requires a respirator.

Jordan David

Fig. 2. Certain conditions call for slip-on mini-crampons.

Steve Lawrence

Fig. 3. Drilling for rafter fasteners while fitted with a work positioning system. Lateral movement is possible anywhere along tension line (protected from abrasion by sliding sheath) and vertical movement is allowed by adjustable body lanyard (extra line hangs from jamming device).

Every time you use your respirator, you must inspect it. You should look for cracks or chips in the faceplate, cracks or holes in the breathing tube or air lines, worn or frayed straps, worn or damaged fittings, bent or corroded buckles and—very important—dirty or improperly seated valves.

If you find anything wrong with your respirator, don't use it. Have it repaired or replaced. OSHA has specific requirements governing the need for and use of respiratory protection if the hazard assessment shows it to be necessary. These include methods for determining the level of need for respiratory protection, selecting and purchasing appropriate equipment, training affected workers to use the equipment and fulfilling the record keeping and medical monitoring requirements. The main responsibility for the timber framer is to know how to inspect and use the respirators properly.

FALL PREVENTION AND FALL PROTECTION. What's the difference? *Prevention,* or fall restraint, is a system that allows you to work close to an edge without the hazard of falling, while *protection,* or fall arrest, is a system designed to protect you if you do fall. Prevention and protection systems might include railings, nets and work platforms that are not PPE, but would also include harnesses, lanyards and associated hardware and anchor points that are considered PPE. Work positioning systems offer prevention while giving mobility during the raising, and rope access systems are very commonly used on timber framing sites. These usually consist of a temporary horizontal or vertical lifeline to clip to, often at the front or side of a harness, while using the fall arrest connection as a backup in case the primary positioning system fails (Fig. 3).

Personal fall arrest systems (PFAS) consist of four pieces of necessary equipment, often denoted *ABCD*—an anchorage, a body harness, a connector and a decelerator. Choosing the right piece in each category is critical to safe functioning of the system and protection of the worker. Ensure that all pieces are compatible with each other and replaced after a fall or if they show signs of wear that could affect their performance (Fig. 4).

Anchorage means a secure point of attachment for lifelines, lanyards or deceleration devices, independent of any other anchorage being used to support or suspend platforms, and capable of supporting at least 5000 lbs. per worker attached. Remember that a fall arrest device is only as good as the anchor point to which it is attached. When choosing an anchor point, be certain that it can handle what's attached: PFAS utilizing a standard shock-absorbing lanyard as a deceleration device must be capable of supporting a 310-lb. person after free-falling for 6 ft. (5000-lb. requirement).

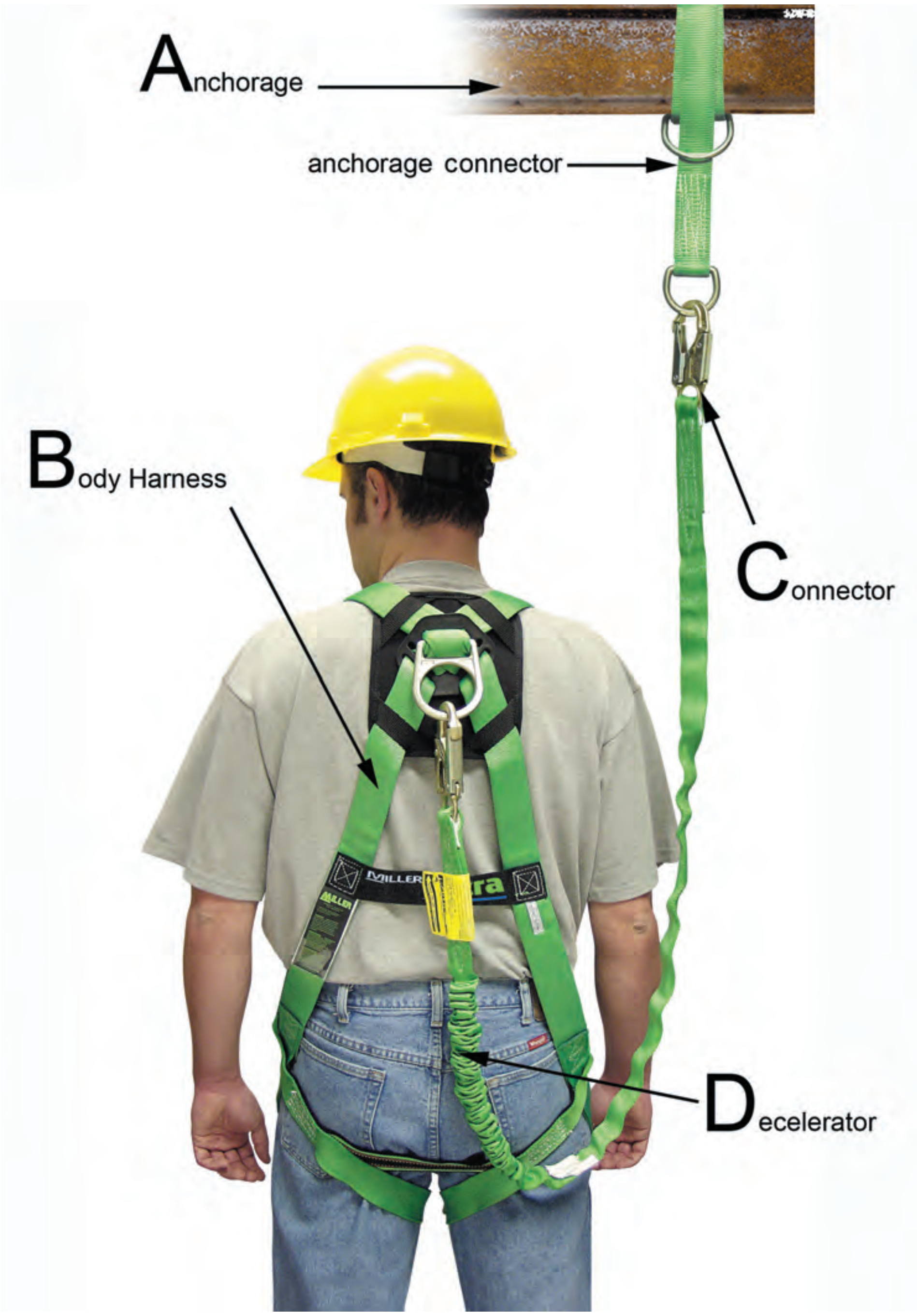
Body Harness means straps secured about the employee to distribute the fall arrest forces over at least the thighs, pelvis, waist, chest and shoulders, with means for attaching it to other components of a personal fall arrest system. Since January 1, 1998, belts have been illegal for use as fall protection. They may, in some circumstances, be used for work positioning purposes only.

Body harnesses, or full-body harnesses as they are commonly called, are designed to protect you from the consequences of falling. For a full-body harness to accomplish this task, several factors must be considered. Perhaps most important, the harness should be adjusted to fit the wearer so that the shock load is distributed evenly. A harness should be snug but comfortable and should not bind the wearer. The sub-pelvic strap should be positioned under the buttocks; this strap and its proper placement are crucial as it dissipates much of the energy generated in a fall. All connectors must be fastened properly, the chest strap must be fastened securely and the dorsal D-ring should rest between the wearer's shoulder blades. If you have the opportunity, shop around for a personal harness that fits you best and allows you to work most comfortably (Figs. 4 and 5).

Connector means a device used to couple or connect parts of the personal fall arrest system and positioning device systems together. It may be an independent component of the system such as a carabiner, or it may be an integral component of part of the system such as a buckle or D-ring sewn into a body belt or body harness, or a snap-hook spliced or sewn to a lanyard or self-retracting lanyard. The lanyards connecting the body wear (harness or belt) to the anchorage are also called connectors (Figs. 6–7).

Connectors come in a wide variety of shapes and sizes. They should be selected with respect to their expected attachment points and fall distance. For example, will the connectors allow the components to fit together properly, and is there a potential for accidental disconnection? (Never connect two hooks, even snap hooks, to each other.) Independent connectors used as attachments to anchorage points or anchorage devices should be considered under the same guidelines. The most important procedure for connectors is inspection before use. A damaged, abused or worn-out connector will render the PFAS component useless, and it must be immediately withdrawn from service.

Decelerator or deceleration device means any connector, such as a rope grab, rip-stitch lanyard, specially woven lanyard, tearing or



Miller Fall Protection

Fig. 4. Personal fall arrest system, comprising ABCD, or anchorage, body harness, connector and decelerator. In this case, a second connector is represented by the strap with hardware wrapped around the I-beam.

Capital Safety

Fig. 5. Full-body harness, front. A harness should fit snugly and distribute the wearer's weight evenly when loaded, but not restrict movement. Compared with harness shown in Fig. 4, this one has not only a D-ring on back (unseen) but also additional D-rings front and sides to connect work-positioning lanyards.

Capital Safety

Capital Safety

Figs. 6–7. Non-shock-absorbing lanyards to be used only as part of a work positioning system. Lanyards in a fall-arrest system, such as in Fig. 4, must have shock-absorbing capacity.

deforming lanyard, automatic self-retracting lifeline or the like, that serves to dissipate a substantial amount of energy during a fall arrest or otherwise limit the energy imposed on a worker during fall arrest. Note that non-shock-absorbing lanyards should be used only as positioning devices as part of the fall prevention system, and not as part of the fall arrest system, which is considered fall protection (Figs. 6–7 previous page).

Most timber framers use a shock-absorbing lanyard, and it's important that the anchorage point for the deceleration device be located as close as possible to perpendicular over the user's head. Diverging more than 15 degrees in any direction from the anchorage point increases the possibility of a pendulum effect upon falling: the person's arc of travel after complete arrest allows collision with the lower level or other obstacles outside of a vertical trajectory. These swing impacts can injure or kill a person who otherwise would have survived the fall unscathed.

Fall protection requirements for residential construction are set out in OSHA's 29CFR 1926.501(b)(13). In general, that provision requires conventional fall protection for work at 6 ft. high or higher. However, in 1999 OSHA recognized the impracticality of installing fall prevention and protection equipment in certain activities and stages of construction, and implemented Instruction STD 3.1, Interim Fall Protection Guidelines, which allows employers to use alternative procedures routinely instead of conventional methods. Certain requirements must be met (see the OSHA website at www.osha.gov and search for Instruction STD 3.1), and conventional PPE must still be worn and used whenever practical during the raising. Often, once the frame is up and an anchor line can be established along the ridge, the usual requirements kick back in.

General rules. Here are some general rules about fall prevention and protection PPE:

Inspect your equipment before each use. Replace defective equipment. If there is any doubt about the safety of the equipment, do not use it.

Replace any equipment, including ropes, involved in a fall. Refer any questionable defects to a trained inspector. (A trained inspector should examine equipment at least yearly.)

Use a shock absorber if the arresting force of the lanyard alone could cause injury.

Use the right equipment for the job. Equipment should be listed as meeting OSHA Standards, ANSI Z359.1, CSA (Canadian Standards Association) Z259, or CE standards (certified in Europe).

Inspection checklist. Here's what to check on your PPE:

Inspect the entire surface of webbing for damage. Beginning at one end, bend the webbing in an inverted U. Holding the body side of the harness toward you, grasp it with your hands 6 to 8 in. apart.

Watch for frayed edges, broken fibers, pulled stitches, cuts or chemical damage. Broken webbing strands generally appear as tufts on the webbing surface. Replace according to manufacturers' guidelines.

Inspect for loose, distorted or broken grommets. Do not cut or punch additional holes in waist strap or strength members.

Check belt without grommets for torn or elongated holes that could cause the buckle tongue to slip.

Inspect buckles for distortion and sharp edges. The outer and center bars must be straight. Carefully check corners and attachment points of the center bar. They should overlap the buckle frame and move freely back and forth in their sockets. The roller should turn freely on the frame.

Check that rivets are tight and cannot be moved. The body side of the rivet base and outside rivet burr should be flat against the material. Make sure the rivets are not bent.

Inspect for pitted rivets that show signs of chemical corrosion.

Rotate the lanyard and inspect from end to end for fuzzy, worn, broken or cut fibers. In a rope lanyard, weakened areas have noticeable changes in the original rope diameter. Replace when the rope diameter is not uniform throughout, following a short break-in period. The older a rope is and the more use it gets, the more important testing and inspection become.

Inspect hardware for cracks or other defects. Replace the belt if the D-ring is not at a 90-degree angle and does not move vertically independent of the body pad or D-saddle.

Inspect tool loops and belt sewing for broken or stretched loops.

Check bag rings and knife snaps to see that they are secure and working properly. Check tool loop rivets. Check for thread separation or rotting, both inside and outside the body pad belt.

Inspect snaps for hook and eye distortions, cracks, corrosion or pitted surfaces. The keeper (latch) should be seated into the snap nose without binding and should not be distorted or obstructed. The keeper spring should exert sufficient force to close the keeper firmly.

Basic care. To prolong the life of a harness and maintain its performance, wipe off all surface dirt with a sponge dampened in plain water. Rinse the sponge and squeeze it dry. Dip the sponge in a mild solution of water and commercial soap or detergent. Work up a thick lather with a vigorous back and forth motion. Rinse the webbing in clean water. Wipe the belt dry with a clean cloth. Hang freely to dry. Dry the belt and other equipment away from direct heat, and out of long periods of sunlight. Store in a clean, dry area, free of fumes, sunlight or corrosive materials, and in a way that does not warp or distort the belt.

LIFTING BELTS AND BACK PROTECTION. The National Institute for Occupational Safety and Health (NIOSH) is the federal institute responsible for conducting research and making recommendations for the prevention of work-related injuries and illnesses. *NIOSH does not recommend the use of back belts to prevent back injuries, as there is no scientific evidence that they work.* Rather than relying solely on back belts, companies should begin to implement a comprehensive ergonomics program that strives to protect all workers. The most effective way to prevent back injury is to redesign the work environment and work tasks to reduce the hazards of lifting. Training in identifying lifting hazards, physical conditioning, stretching exercises and using safe lifting techniques and methods should improve program effectiveness.

Safe lifting techniques. The risk of back injury through improper lifting is perhaps the most common hazard in the timber framing industry. Here are some pointers from the American Academy of Family Physicians—some, if obvious, frequently forgotten:

Test every load before lifting by pushing the object lightly with hands or feet to see how easily it moves. This procedure tells you about how heavy it is. Remember, small size does not always mean light load. Be sure you have a tight grip on an object before lifting.

Do not arch your back when lifting a load over your head. You can injure yourself.

Use slow and smooth movements when picking up an object. Hurried, jerky movements can strain the muscles in your back.

Keep your body facing the object while you lift it. Twisting while lifting can hurt your back. Keep the load close to your body. Having to reach out or over something to lift and carry an object may hurt your back. "Lifting with your legs" should be done only when you can straddle the load. To lift with your legs, bend your knees, not your back, to pick up the load. Keep your back straight. Whenever possible, carry the load in the space between your shoulder and your waist. This puts less strain on your back muscles.

Pace yourself. Take many small breaks between lifts if you are lifting a number of things.

Fig. 8. Carrying an unbalanced load safely and restfully (at least one of the two men on the short beam is loafing). Everyone faces squarely forward and stands nearly upright; the cart takes the brunt of the load as the fulcrum between the long part of the post and the beam-brace assembly on the short part.

Will Beemer

Don't overdo it—don't try to lift something too heavy for you. If you have to strain to pick up or to carry a load, it's too heavy. Get help! Use an assistant, a cart, a dolly or whatever is to hand (Fig. 8).

Communicate with your partner(s) when lifting, carrying and setting down timbers. If someone drops or picks up a timber unexpectedly, it can result in crushed fingers or worse. Never drop one end of a timber when you are carrying it with someone else as this can seriously injure your lifting partner.

Make sure you have enough room to lift safely. Clear a space around an object before lifting it. Look around before you lift, and look around as you carry. Make sure you can see where you are walking. Know where you are going to put down the load.

Avoid walking on slippery, uneven surfaces while carrying something. Avoid stepping over objects while carrying a load. It's better to hand the object to someone standing on the other side or on another level.

Don't rely on a back belt to protect you. Remember, it hasn't been proven that back belts can protect you from back injury.

Large timbers requiring more than two people are awkward to help carry and walk beside because the body must be twisted to do so. Instead, use a 2x4 or strap under the timber and carry it with a partner so you can point your body in the direction you're moving.

Because of the high incidence of back injuries, safe lifting techniques for manual lifting should be demonstrated and practiced. OSHA recommends using a formal training program to reduce materials handling hazards. Instructors should be well versed in matters that pertain to safety engineering and materials handling and storing. The content of the training should emphasize factors that reduce workplace hazards. Workers should be instructed in the proper use of equipment and taught to recognize potential hazards and how to prevent or correct them.

Any program should alert workers to the dangers of lifting without proper training and show proper body mechanics to avoid unnecessary physical stress and strain. It should demonstrate how to stretch and prepare for the workday mentally and teach workers to become aware of what they can comfortably handle without undue strain.

—Will Beemer

RESOURCES

Capital Safety. www.capitalsafety.com. Fall-protection and work-positioning equipment and netting systems. 1-800-328-6146.

Jordan David. www.JordanDavid.com. Source for Grip-X mini-crampons.

Lab Safety Supply. http://www.labsafety.com. Free catalog of a vast selection of Personal Protective Equipment. Their website also features a good Info Library that includes a Resource and Training Center. 1-800-356-0783.

Miller Fall Protection. http://www.millerfallprotection.com. Good source for products, training and information about harnesses, lanyards, work positioning and fall protection. 1-800-430-5490.

OSHA. http://www.osha.gov. This website details the general requirements for PPE (Standard 1910.132), but also has user-friendly interactive "e-tools" and safety sheets, posters for display in your shop and publications to distribute to your employees. All free. From the OSHA homepage, search for "Personal Protective Equipment."

Petzl. http://en.petzl.com/petzl/ProAccueil. Petzl manufactures helmets, harnesses, fall arresters, work positioning equipment and more. Their website has a wealth of information. If you look into the Products and Activities sections of their Work Solutions page, you'll find videos and other interactive tools for choosing, using and inspecting PPE. Click on an individual product to see these Technical Notices.

PPE course. http://www.free-training.com. Free online course for Personal Protective Equipment with test.

The English Barn in America

IV. Raising the Timber Frame

THROUGHOUT my 30-plus years in timber framing, I have regularly raised my timber frames as traditionally as possible, employing human power and a hoisting apparatus. Only two of my raisings relied on a fossil-fueled lifting device (crane) and only because of special circumstances. This is quite ironic: my father made his living operating cranes and, since I was a boy, I have been fascinated by those wonderful machines. A further irony is that in the 1960s my father demolished numerous old timber-framed buildings in the name of progress. I watched for hours as that clamshell bucket tore away chunks of wood and brick. And, since 1976 I have been building new frames and raising them by hand!

As my own English barn was nearing completion, I discussed the raising party with my insurance agent. I envisioned 50 or more friends and neighbors coming with a dish to share, and assisting in the work. There would be music, a fire and, of course, libations after. What better way for a building to start its life? After talking with the agent, however, reality set in. If anyone were injured, I would be the responsible party. After all, I was the owner, the architect and the builder. I was supposed to be knowledgeable about fall protection, hardhats, steel-toed boots and approved scaffold planks. An OSHA-compliant raising would not be a raising in any traditional sense. On one Friday afternoon following another long phone discussion with an insurance professional, I walked out of my office and without another thought began to raise the building by myself.

Now, I had reared a number of smaller outbuildings (10x12-ft. range) by myself over the years, but never a building of this size (two stories, 25 ft. 6 in. x 34 ft.). Was it feasible for a 50-year-old with back problems? My curiosity also came into play. Our English timber framing colleagues inform us that their buildings often go up one piece at a time and probably did so in the past; many of their framed structures don't lend themselves to the raising of assembled sections or bents. I was eager to try the piecemeal technique to study its suitability in raising English barns here.

Though traditional structures were undoubtedly framed and assembled using a crew of workmen, I would be going it alone. To assist me, I would use an ancient, simple hoisting device, the gin pole. (Its name doesn't derive from the liquor but from the word en*gin*e, itself descended from the Latin *ingenium*.) The gin pole is mentioned in period literature. It is pictured in works as early as Alberti's *On the Art of Building,* 1486 (Fig. 1).

Over the years, I have encountered two original 18th-century gin poles, one framed up as a rafter in an English barn in Goshen, Massachusetts, the other cut into lengths to make floor joists in a Connecticut barn. Both poles were tapered octagons; one was painted. Noted barn specialist Richard Babcock, for whom I worked periodically in the 70s, introduced me to the gin pole in 1976. He often used it for dismantling and raising barns. In fact, on one large German barn, he used two gin poles simultaneously to lift the heavy swing beam bent.

During this one-man raising, I endeavored neither to strain myself physically nor to attempt any dangerous maneuvers. I was successful on both counts. The work was carried out over several days and totaled only 30 hours. Though a raising party could have reared this frame quickly in bents, either by crossframe or long-wall method, a very small crew raising it piecemeal would have been an effective and economical method.

I began with the southwest jowled corner post by raising it Iwo Jima-style, having previously attached a long roughsawn 2x4 brace (by a single 20d duplex nail) high on the post to brace it transversely once erect. A block nailed on the sill extension (leaving those sills long was handy) kept the bottom of the post from sliding off as I tipped it up and it found its mortise. Once vertical, the post would stay by itself, barring any wind gusts, until I plumbed it and secured the bottom end of the brace. I then nailed on a second, longitudinal brace, plumbing the post in the long wall direction. Next came the door stud and two wall girts, assembled into their mortises and pinned temporarily with iron hook pins. Long, light temporary braces (14 to 16 ft.) temporarily secured these members from side movement. As I brought the second wall post to vertical, I guided the two girt tenons into their mortises and pinned them. This post is plumbed transversely and secured with a temporary brace. It isn't necessary to add a longitudinal brace on this post as it is secured, through the girt, to the first post. One temporary brace per wall or crossframe is sufficient. Over the center bay, there is only the long door header connecting the posts. Too high to place from the floor, this piece required a stepladder and a prop temporarily nailed on at the proper height to hold up the free end (Figs. 2–3).

When the west long-wall posts were up, I worked across the south wall and then progressed toward the north, repeating the steps. The four interior transverse girts, 12-ft. 6x8s, were too much to lift and position alone, especially the yellow birch and elm ones. Here I employed my refurbished and modified circa-1900 tripod, originally used to lay water pipes in the streets of Northampton, Massachusetts. It has 15-ft. spruce and balsam fir legs, a 2:1 ratio block and tackle and a boat winch (Fig. 4).

With its aid, the girts rose effortlessly, intermediate studs could be installed and the girts lowered onto their tenons. Where there were no supporting studs, the tripod held the girt till the necessary post was raised. The only disadvantage to a tripod is taking it

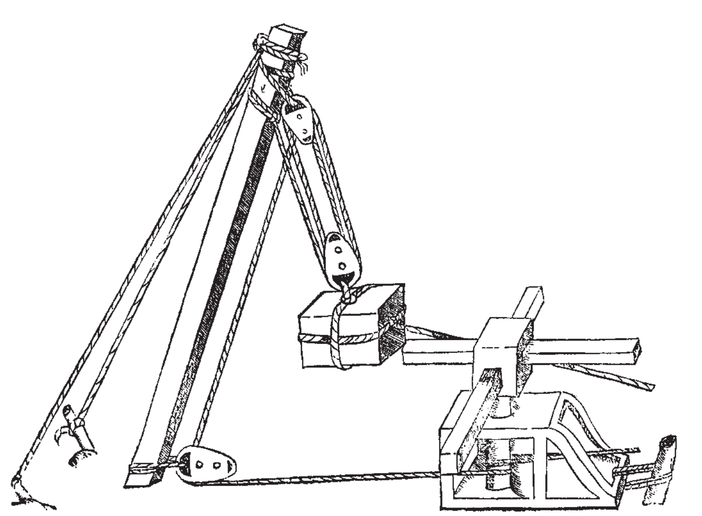


Fig. 1. Representative drawing of windlass, gin pole and load with tagline from Alberti's* On the Art of Building, *1486.

Photos Jack A. Sobon

Figs. 2–5. Fig. 2, top left: by main force, author raised first corner post prepared with one pivoting strap and footed against block nailed to sill, added short post and two girts, then raised second post in line with sill. Fig. 3, at left: first long wall posts up and braced. Fig. 4, above: tripod worked well to hoist and position heavy loft girts in the intermediate crossframes. Boat winch has two speeds. Fig. 5, below: all the outside wall and interior posts await plates and ties.

down—one leg has to be passed over the girt. For the last post, a corner post, only the end-wall girts were in place. After I engaged it on the two girt tenons, I tilted out the post to insert the door header. All the posts were now in place (Fig. 5).

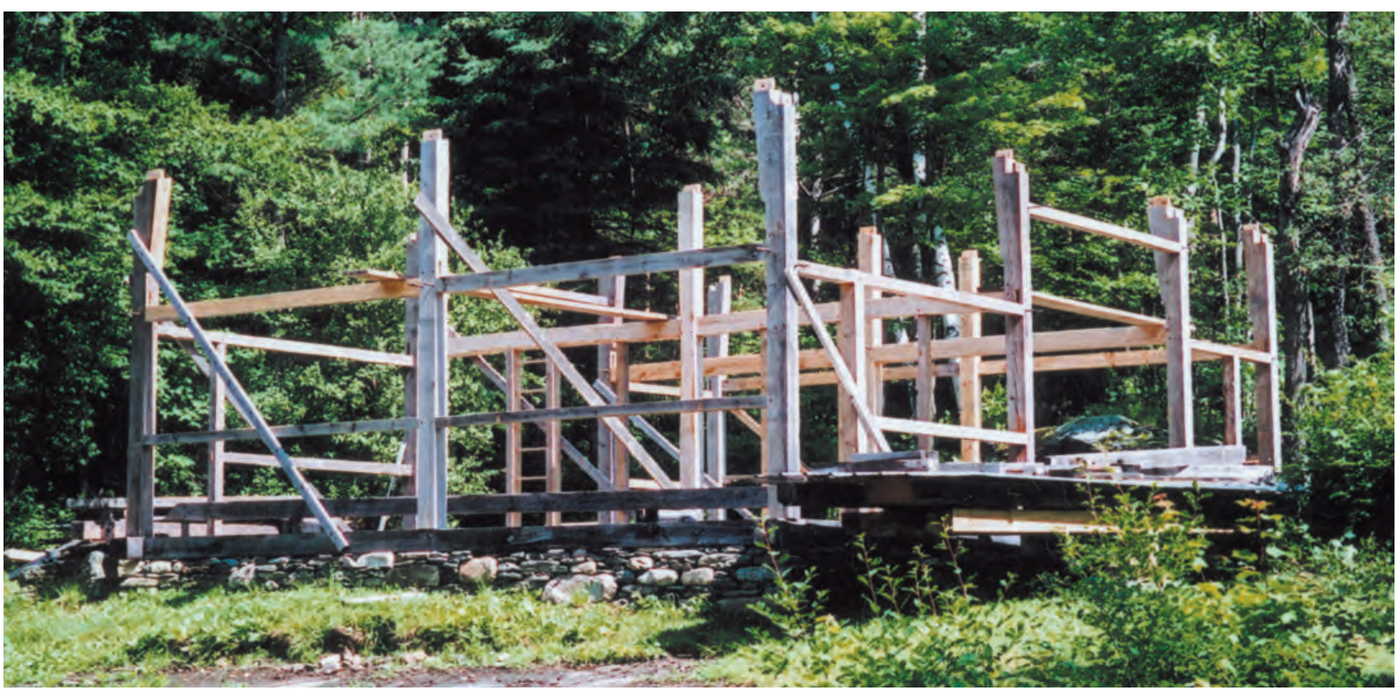


Fig. 6. Gin pole helps lift plate and position one end over a corner-post tenon. Planks give access for adjustments and brace insertion.

Fig. 7. Choker grip for the load tackle and three guy lines (one fore, two aft) complete rigging at top of gin pole.

PLATES AND TIES. Next came the plates, long and fairly heavy, too high a lift for the tripod and so a job for the gin pole. My gin pole is a straight spruce pole, peeled and dried, 26 ft. 6 in. long, tapering in diameter from about 5½ in. at the butt to about 3 in. at the tip, smooth except for a few short branch stubs left near the tip to keep the rigging from sliding down the pole. About 3 ft. up from the bottom, a bored hole accepts a wood pin for lashing the hoisting rope. The butt of the pole has a 1½-in. tenon, 5 in. long, that fits into the middle of a 6x6 base timber 8 ft. long. The pole is loosely pinned to the base with a hook pin (Fig. 6).

This base (not visible in the photos) serves three functions. It spreads out the load if the gin pole is on soft ground or a floor deck, it makes the pole easier to move around when rigged vertical, and it makes raising the pole itself easier. Because of the weight of the base, the pole can be raised by one person without it over-toppling. Even with the base, however, the pole cannot be raised single-handed with the considerable weight of the rigging on it.

I leaned the pole across the wagon door header so I could reach the tip from my scaffold. About a foot from the top, I wrapped a short rope six to eight times around the pole and tied it loosely. Pulling out the top three turns, I hooked the block and tackle there. The other few turns acted as a choker to grip the pole tightly, preventing slippage. Above this I tied the three guy lines. The two back ones hold the load while a single one in front keeps the pole from falling backward from the weight of the two back guys (Fig. 7).

For the two back guy lines, I use a single 200-ft. ¾-in. Manila rope with a clove hitch in the middle over the pole. This knot is quick to tie and easy to slip on and off. The front ⅝-in. guy rope is tied to the pole. The two double-sheave pulley blocks are rigged with ⅝-in. rope and give me a 4:1 mechanical advantage, discounting friction losses, so that with my own weight I can lift a 900-lb. timber. Though, for heavier lifts, I have a bigger set of triple blocks rigged with ¾-in. Manila rope, 1-in. guy line and a larger gin pole, my smaller pole and rigging were sufficient here. The dead ends of the guys are wrapped three times around distant trees or other immovable objects, and knotted. (The wraps relieve the knot of any strain.) Enough slack in the lines is left to allow the pole to rise as its base moves toward the building.

To raise the plates, I positioned them alongside their respective walls for a direct vertical lift. I maneuvered the bottom of the gin pole into position midway down the wall and about 3 ft. away, with the block and tackle allowed to hang loosely to act as a plumb bob. The rear guy lines were snugged up until the pulley block dangled almost over the plate, the pole leaning forward a little under load, and the front guy line then tightened up. I used nylon straps to attach the load to the hook, but two loops of Manila rope could be used. A 20-ft. length of ½-in. rope tied to the lighter end of the plate served as a tag line to guide the plate from the ground (Fig. 8).

I hoisted the plate higher than the posts and tied off the hoisting rope. Using the tagline, I swung the plate so that the heavy end rested on a post top tenon. By backing off on the rear guy lines, I was able to swing the plate over the remaining posts. I let off on the hoisting rope enough to sit the plate on the four post tenons.

Fig. 8. Gin pole (now inside frame) is placed carefully for load block to hang plumb over destination. Tagline (slack at left) controls load.

To provide a scaffold for working the plates, I had laid planks across the loft girts. From this scaffold, I now inserted the four braces. Because they rested on the girt, the bottom tenon of each could be slid out enough for the brace to engage both plate and post mortises simultaneously. Back on the ground, I loosened the hoisting rope, letting the plate down some, then climbed back aloft to drive the plates home with a commander. I then pinned all the associated joints permanently.

The guys to the gin pole could then be loosened to lean it against the plate for removal of the rigging. I moved the pole to set the opposite plate, this time inside the building. Though the pole was positioned thus to avoid a pile of timbers, its location inside the frame became an advantage for later picks. By spinning the pole, I could set the two interior tie beams, resetting the guy lines of course each time, but leaving the rigging on the pole. With a crew of four, a gin pole would be easily turned. With the pole vertical, one person rotates the pole base while the three others, each on a guy line, walk in a circular path. Working alone it's a bit trickier. I spent a substantial portion of the 30 hours' raising time rigging, derigging and moving the gin pole.

I set the tie beams on the sills next to their respective posts and lifted them up inside the building, easily snaking them back and forth to clear the scaffold planks and plates (Fig. 9).

When they were positioned above their posts, I inserted their braces. I tapped the ties carefully down into position, since both upper and lower sides presented joinery that could be easily damaged. When the four ties were in place, the structure was fully braced and the temporary braces could be removed, but I left them for additional insurance until the building was roofed and sheathed.

PRINCIPAL RAFTERS. The principal rafter pairs were next. I ran scaffold planks across the tie beams for a working platform. Though I'm used to working off spaced planks, as shown in Fig. 9, sheets of plywood over them would have formed a safer working surface. I hoisted the rafters and collars individually up to the roof level with the gin pole and assembled the two intermediate rafter pairs. To do so, first I inserted and pinned a raking strut into its tie,

Fig. 9. Three of the four ties in place over teazle tenons on posts and dovetail housings on wallplates. Spaced planks give access to connections as they are made up.

Fig. 10. Gable rafter pair with collar assembled over spaced planks on tie beams. Already erect, one intermediate rafter pair with raking struts was assembled piecemeal in position. Note notches for ridge and purlins. Detail below, closeup of stop nailed to tie to restrain rafter foot when truss is lifted.

then picked up a rafter and engaged its foot in its mortise in the tie, then lowered the rafter over the raking strut, finally inserting a loose pin at the rafter foot joint. The opposing rafter went up by similar steps but, in addition, it had to engage the first rafter at the peak. With the exception of pinning the peak later (when the purlins were in place and planks run athwart them as a scaffold), all the work could be done from the platform.

The north gable rafters with collar gave no problem assembled flat and, being quite dry and lightweight, it was easily tipped up and into its mortises. Blocking nailed to the side of the tie beams prevented the assembly from sliding off the building (Fig. 10).

I assembled the remaining gable rafter pair with collar on the ground outside the building and used the gin pole to hoist it into place. Using a plumb bob, I plumbed this gable and braced down to the plate. Though rafter pairs will stand on their own, bracing them at this stage was far easier than racking the roof later with the purlins in place. If I had applied the brace to the underside of the rafter, it could even have remained in place until the roof was sheathed and covered (Fig. 11).

Fig. 11. Stay braces for rafters will keep roof framing plumb. With forethought, they would have been nailed to undersides of rafters.

THE PURLINS. Installing the roof purlins, nearly 36 ft. long, called for the gin pole to be set up again alongside the building. I had left some of the tie beams long, hanging out past the plate, with the intention of setting purlins up there where they would be close to hand for installation. (I saw this technique mentioned in a book and thought I'd find out if it had some merit.) The long ends were certainly advantageous as a staging level for getting the purlins, but sawing or hewing them off later proved quite tedious. Next time I'd cut them off while on the ground. Planks can be run out instead to stage the purlins (Fig. 12).

Fig. 12. Raising purlins with the gin pole and staging them on projecting tie beam ends left long for the purpose.

Fig. 13. Square ash pin securely grips pine purlin-to-rafter joint.

Fig. 14. Plank across purlins allows installation of lightweight ridge.

At any rate, I rolled the purlins on their backs, slid them up the rafters and flopped them into their notches. Each rafter crossing I pinned with a square, riven, blunt-pointed pin. A 13⁄16-in. square pin driven into a 13⁄16-in. diameter hole has amazing draw-down and holding power (Fig. 13).

Once finished with this side of the roof frame, I nailed on a diagonal 2x4 wind brace so the opposite side's brace could be removed to install its purlins. I moved the gin pole one final time to bring up the remaining purlins. To fit the ridgepiece (secured with cut nails because there was insufficient wood at the peak to pin this joint), I set planks across the uppermost purlins to serve as a scaffold (Fig. 14).

The frame done, the final act of a raising, of course, is to fasten a small upright evergreen to the inside of the end gable peak. Usually this is done jointly by builder and owner—in my case one and the same. This act gives thanks for a safe raising and to the forest for all it has provided. In old structures, one occasionally finds the stubs of these small trees still intact. Perhaps it was bad luck to remove them completely, so they were cut off flush for the roof sheathing. Though nailing a sacrificial tree to the frame may seem a bit superstitious, it makes perfect sense to me (Fig. 15).

In the final article in this series, we will see the barn sheathed and roofed, doors and floors installed and gutters applied, with lessons learned as well as a few tricks and shortcuts. —Jack A. Sobon

Fig. 15. The frame complete, ready for the wetting bush, shown with the author in circular inset.

HISTORIC AMERICAN TIMBER-FRAMED STEEPLES

I. Middlebury, Vermont

This article is first in a series to discuss the form, function and joinery of selected historic American timber-framed steeples. The series was developed from original research under a grant from the National Park Service and the National Center for Preservation Technology and Training. Its contents are solely the responsibility of the authors and do not represent the official position of the NPS or the NCPTT.

> One of the peculiarities remarkable about Wren's period is the investment of the form of the Gothic spire with a clothing of Italian Architecture, by which the modern steeple was produced. (J. Gwilt, *The Encyclopaedia of Architecture*, 1867)

THE tall, storied steeple of the Middlebury, Vermont, Congregational Church (1806-09) is an outstanding example of Federal architectural design and of substance and sophistication in heavy timber framing. The church is 59 ft. wide and a shallow porch protrudes 5 ft. forward across the central 34 ft. of the façade. A 17-ft.-square tower, or plinth of a tower, decorated with quoins, rises from the porch and from the frame of the roof system, with another 17-ft.-square tower, this one with ranked pilasters and arched niches, some open and some blind, rising another 14 ft. above that. This second stage of the tower may be called the belfry for it carries the large bell.

A square lantern of somewhat smaller footprint rises next, with ranked, fluted pilasters and large clock faces, added in 1853, that unfortunately interrupt the original design of ascending arched windows. Above that, the first octagonal lantern emerges and then a shorter octagonal lantern above that with elliptical fenestration. This second lantern is surmounted by a spire, ball and vane, of which the comet-form arrow is itself 6 ft. long. The overall height to the top of the vane is 135 ft., but the church's position at the crest of a hill above the center of the village makes it appear taller (Fig. 1).

Middlebury's architect was Lavius Fillmore, self taught, with origins as a master framer of churches and other large structures. The actual framer appears to have been one Martin L. Crandal, who advertised in the local newspaper for "15 journeymen joiners" (*Middlebury Mercury,* Feb. 5, 1806). Glen Andres's extensive research on the origins of the Middlebury design and its development from Fillmore's other churches in Bennington, Vermont, and East Haddam and Norwichtown, Connecticut, will give a much fuller picture of the architecture of this structure (Andres 30-42).

The exterior design of Middlebury's steeple is based on the works and publications of the British architects James Gibbs, Christopher Wren, Robert Hooke and Nicholas Hawksmoor, and their American successors such as Joseph Brown.

Similar designs, previously rendered in masonry in England and continental Europe, are here translated into wood, as was done by Brown in his First Baptist Church of Providence, Rhode Island. Each story is deeply telescoped into those below it and, while the telescoping itself is normal for the period, the great density and interconnectedness of the Middlebury frame is remarkable. Unlike the derived architectural style of the steeple, its framing is reflective of a region possessing vast native supplies of extremely large, old-growth timber. Fillmore and Crandal's attempt to produce an immensely weighty and relatively inflexible very tall object sets it apart from many other steeple frames of the period that have quite opposite aims, namely lightness and flexibility.

Middlebury's timber is all oak (red and white) and pine (white and possibly red). Many of the largest sticks such as truss chords and tower posts are hewn pine, but as often the tall posts are oak. The timber, almost free of wane and with few knots, is hewn and sawn to great smoothness and regularity. All the smaller timber, such as for braces, is oak, vertically sawn. There is plenty of evidence of both the square and scribe rules at different points in the steeple; when making unique assemblages in a frame, there is no special virtue to the square rule. Some of the largest columns in the tower, 12x12x28 and larger, carry Roman numerals matching those on the crib timbers they bear upon, possibly related to the order of assembly in this complex frame as much as to scribing.

THE STRUCTURAL FOUNDATION. Middlebury's weighty steeple is integrated with the exterior and interior design of the church. The front of the tower appears to rise from the front wall of the portico, although the two front tower columns disappear from sight descending inside the portico wall, dropping ultimately to the sill and limestone foundation at grade, a feature shared with Brown's First Baptist of Providence. Longitudinal 12x14 main sleepers tenoned into these front posts right above the interrupted portico plate cross the 11x13 front wall plate of the church 5 ft. inward, and then the fully supported vestibule wall 12 ft. farther inward, ultimately terminating over the lower chord of the second interior kingpost truss. This truss is in turn propped by colossal columns rising through the audience room, supporting the galleries, passing through two levels of decorative capitals and tenoning into the truss several feet to the outside of the sleeper (Fig. 2).

The rear columns of the first stage of the tower rise from these main sleepers slightly forward of where the latter cross the first interior truss. As is common in steeple framing, these posts are treated as queenposts in a truss to help carry the steeple load, but in this case the main braces rising to the tower queenposts are slightly out of plane, originating as they do on the truss chord centered 1 ft. behind the centerline of the posts on the sleepers. This combination of support systems for the steeple—portico plate, front wall, sleepers, vestibule wall, queenpost trussing of the rear columns and colossal columns assisting both the first and second interior trusses—apparently was not enough to stop some rearward lean of the steeple. The evidence is open (and now filled) joinery shoulders on the slack side, and the presence of later-added timber bracing on the compression side, the latter rising from the sleepers and first and second interior truss chords to the rear tower posts.

While backward lean is common in steeples where the rear of the steeple bears on an open span truss unsupported by intermediate walls or columns reaching to the ground, the declination of the rear of the well-supported Middlebury frame may be a result of combined factors: accumulated shrinkage of the several layers of timber supporting the rear, shrinkage across queenposts (which allows the truss to sag to take up slack in its compression joints), minor bending made possible by the small offsets between truss chord, sleeper and queenpost and, finally, even the out-of-plane configuration of the queenpost main braces. The kingpost truss right behind the tower queens can also be expected to sag a bit from settling and shrinkage across the broad head of the kingpost and across the feet of the low-pitched principal rafters and their chord ends. Shims in the kingpost truss joints indicate that their share in the problem has been jacked and partially remedied at least once in the past.

The tall front columns of the steeple rest directly upon a sill (invisible but likely 10 to 12 in. tall) at the foundation, but the rear columns bear first upon a multiplicity of deep sleepers, truss chords and truss elements capable of shrinkage and great compression from oblique bearing and bending moments, before their load is carried down to the foundation. The sum of horizontal-timber depth immediately under the rear steeple posts is 27 in., and the cross-grain shrinkage of this pile of oak, about 2¾ in. from green to dry, is augmented by wall plate shrinkage where the trusses bear, as well as the other sources of deflection cited.

Evidence that the rearward sag in the Middlebury steeple should be attributed to shrinkage is the observed incipient failure in tension perpendicular to the grain of the top surface of the east sleeper's tenon in the front column, a consequence of the beam dropping relative to its tenon and the pins that transfix it. While timber is famously resistant to such failure, distortion first shows up as local bending of the member and compression in the bottom edge of the vertical tenon. Fortunately, the tenons are assisted by original ½-in. x 2-in. iron straps 36 in. long, fastened by six large hand-forged spikes, helping to tie the joints. Shrinkage of the 13-in.-deep front wall plate 5 ft. inward of the tower front, and then roughly twice as much shrinkage (based on 27 in. of timber depth) another 12 ft. rearward at the rear tower columns, would account for a gradual decline of the tower to the rear. If truss sagging or another problem at the rear of the steeple were the only problem (as it usually is), the sleepers would be cantilevered across the fully supported front wall plate and their tenons would be forced upward into their mortises in the front columns rather than dropping downward as they can be observed to do. The sleeper appears to be dropping downward at the face of the mortise, leaving its cracked upper portion behind, hanging on a pin.

If 12x12x60 timbers are available to stand upright, their potential aid in assembly and lifting and their advantages in axial loading, lack of shrinkage, and increased stiffness and stability of the tall object to be framed are hard to ignore. However, the framer has to balance the absence of both shrinkage and side-grain compression at the gloriously simplified front with shrinkage and compression at the complex rear of the same frame.

It is difficult enough to get the right initial amount of camber in trusses, allowing for later shrinkage and compression. In the usual steeple situation—front wall posts as tall as the side wall posts and a front plate as large as the truss bottom chord, so that shrinkage of the underlying support is equal front and back—the problem is then produced at the rear by truss sagging and shrinkage, or bending of the bottom chord when loaded between points of support.

At Middlebury, the tall posts complicate matters. For the tower base to come level after seasoning, the front wall plate 5 ft. in from the front columns would have needed to be made taller (deeper) to begin with, or columns within the front wall allowed to rise directly under the sleepers to support them pitched upward to the cambered trusses. The result would have been a steeple frame pitched slightly forward when new, waiting for years to settle to level.

Ken Rower

Fig. 1. Middlebury Congregational Church (1806–09), designed by Lavius Fillmore, stands at the top of a hill at an important road junction. Fig. 2, below, post at left rear rises through vaulting to help support a roof truss carrying back wall of steeple.

THE TELESCOPING FRAMES. The interpenetration of tall exposed frames into the frames or masonry stages below them is common worldwide in churches, temples and other tall structures, and good practice even for the cupolas of large New England barns, where cupola posts often drop 12 to 16 ft. below their apparent perch on the roof to tenon into heavy timber sleepers crossing two or three upper tie beams. Steeples without some degree of telescoping among the stages are rare, possibly because of the high tendency for those stages to be blown off by calamitous winds in the absence of some other anchoring measure or a benign topographical location.

There are two general strategies of telescoping, with many variants. The first inserts a stage for a relatively short distance within the previous stage and links the two tightly with girts, bracing and skirting roof framing, restraining the upper stage mostly by attachment to the mass of the lower stage, a sort of vertical cantilevering or anchoring. The second strategy inserts an upper stage deeply within a lower stage, perhaps establishes extensive bracing among the upper stage posts inside the concealed space and is only connected to the lower stage framing or masonry incidentally by flashing and small dimension roofing materials. In the second case, the upper stage mostly restrains itself by having a greater portion protected from wind pressure than the exposed portion. The framers at Middlebury, leaving no stone unturned, no opportunity unexploited, used both strategies.

The six stages of the Middlebury Congregational Church steeple comprise three square frames, two octagonal frames (the upper and lower lanterns) and a culminating tapered octagonal spire (Figs. 3 and 4).

Tower and belfry. The first and second stages, respectively the tower plinth and belfry, although visually separated on the exterior by a large cornice and distinct architectural detail (Fig. 3), are supported by the same tower frame: 12x12x60 tower posts rising from the sill at the front and 12x12x30 rear tower posts rising from the main sleepers and complex framing. Where tower plinth becomes belfry at the top of the first stage, the immense bell deck sleepers are lodged on two levels of 10x12 girts joined by short struts and supported by long 4x6 oak braces (Fig. 5).

The five parallel bell deck sleepers run transverse to the axis of the church and parallel to the swing of the bell. They increase in size from the outside to the middle, becoming as large as 18x22. These timbers are sized to span the 17-ft. width of the tower and carry the weight of the bell and its dynamic loads. They also serve as bearing for the 28-ft. columns that frame the third square stage next above and, with the help of the mast, transmit all the loads from the remaining stages above.

At the top of the belfry, the tops of the four corner columns of the tower are joined diagonally by the immense lapped double-cambered ties of the original mast base, which sit upon the post tenons. Girt timbers 10x10 tenon into these posts slightly below their tops and are double-braced by two different lengths of parallel 4x6 bracing (Fig. 6).

Clock stage. The third stage, the clock stage, is still square in plan but smaller than the tower and belfry stages, though architecturally similar. Since 1853 it has displayed the clock, perhaps enhancing the timeliness of the citizens, but interrupting the graceful vertical development of Fillmore's design by almost entirely occluding the arched windows behind the clock faces (Figs. 1 and 3).

The eight 12x12x28 columns flanking the corners of this stage began approximately 14 ft. lower at the bell deck sleepers, rose hidden within the belfry interior sheathing, and now emerge to view as the visible steeple frame for another 14 ft. (Fig. 21). As these paired columns emerged from the belfry roof, they clasped the immense diagonal double-cambered ties of the original mast foot (Figs. 6 and 11).

The four pairs of columns terminate in a 12x12 plate at the top of the clock stage. At this level, 10x12 mast partner timbers lap into and over this plate, two on each side. These partners clasp the mast at their middle and also lap over connecting girts within the fourth stage framing, the first octagonal lantern frame, already telescoped within the clock stage at this point. To add complexity to this junction, the crib timbers for the *fifth* stage, the second lantern, bear upon these partners, locking the lap joints with thousands of pounds of superimposed weight from the stage, spire and vane above (Fig. 7).

First octagonal lantern. The fourth stage, the first octagonal lantern, has the first true octagonal frame. (The clock stage below, though square on the exterior, is actually framed with eight posts forming an irregular octagon.) Its posts began in mortises at four crib timbers lodged upon the large double-cambered beams of the original mast foot at the top of the second (belfry) stage. This first octagon is telescoped within the clock stage for 15 ft. and then emerges for 12 ft. as a windowed lantern 9 ft. 8 in. across the flats. About 9 ft. up on each of the five-sided octagon posts, still within the clock stage, 3x5 diagonal braces rise and tenon into the eight facets of the mast, all the tenons being wedged at both ends.

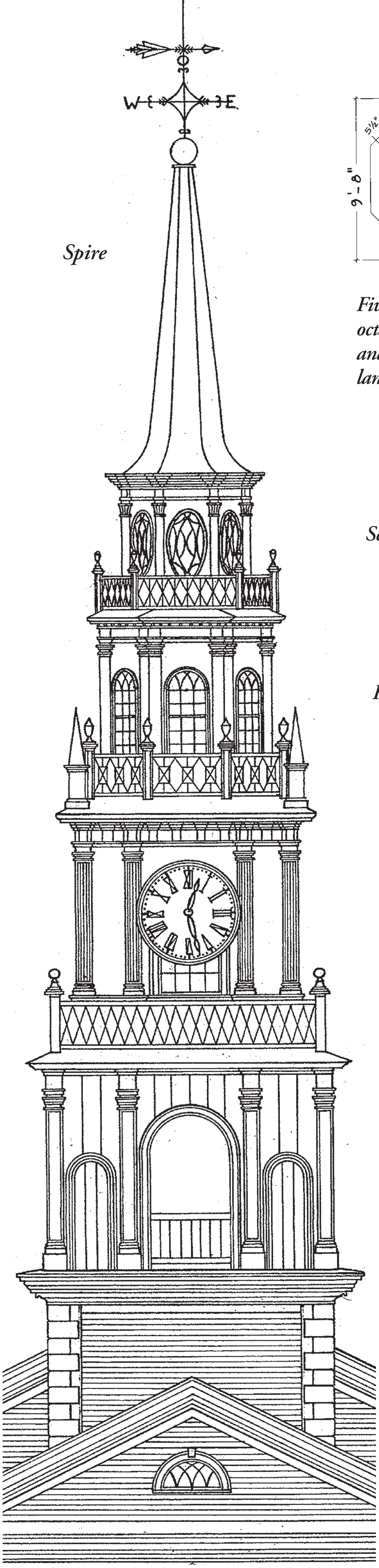
Shortly above that point the pairs of octagon posts are joined by pairs of crossing braces (X-bracing) that tenon into the posts themselves at their feet and the octagon connecting girts at their tops—the same connecting girts lapped by the partners mentioned in the discussion of the clock stage. This lantern's five-sided posts pass through the partners, snugged against the outside of each member of the pair, rise 12 ft. and terminate in a short tie. Just below the tie lies a girt lapped by another set of partners, lapping a second octagonal lantern girt as well and clasping the mast (Figs. 8 and 16).

Second octagonal lantern. The fifth and last stage before the spire is the upper octagon, with its elliptical fenestration. Its eight five-sided oak timbers began approximately 11 ft. below within the lower octagon, at the crib timbers atop the partners at the top of the clock stage (Fig. 6). This upper octagon has become smaller, 7 ft. 3 in. wide across the flats, and exposes 9 ft. of height to wind and view. X-bracing and connecting girts lie right beneath where it emerges, and the set of partners that laps into the lower octagon plate also laps over these connectors before clasping the mast (Figs. 8 and 16).

The interior of the exposed portion of the upper octagon is full of diagonal braces, 16 of them dividing the space. Eight 3x4 braces rise from mortises in the mast and tenon into the inside faces of the five-sided octagon posts. Only 2 ft. above these latter connections, another set of eight braces rises from mortises in the posts to tenon into the bottom of the crab that ties together the plate level of the stage and also serves as the base of the spire framing.

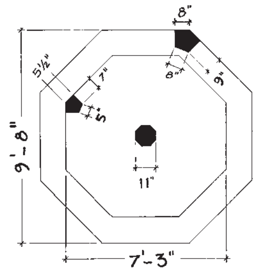
The eight legs of this uppermost crab, or star as it is sometimes called, join ingeniously to the mast and can be seen as interrupted tie beams across the octagon. The rigidity of this crab is reinforced by a ⅜-in.-thick iron ring set 4 in. away from the mast, crossing all the legs and spiked to each of them twice (Figs. 9 and 18).

Spire. The sixth and final stage is the tapering spire itself, amounting to 19 ft. additional of framework plus the 20-in.-dia. ball and 10 ft. more of weathervane. As often in spires, this stage is dense with framing. The octagonal mast rises undiminished through the spire to its top where it supports the ball and vane. Oak spire rafters 3½x4 descend from the top to bear in wedged mortises in the crab atop the upper octagon. Just 3 in. inboard from these rafters, eight identically sized oak braces rise from wedged mortises on the crab legs, 19 in. out from the arrises of the mast, and climb a slightly lesser angle to mortise into the mast 9 ft. 10½ in. above. A hammered iron hoop binds the eight inner braces about 9 ft. above the crab. There appears to be another iron hoop around the spire rafters toward the apex, but the space is too full of timber to permit direct examination.



HABS

Fig. 3. Historic American Buildings Survey drawing V-11 of Middlebury, detail from sheet 3, front elevation.



Five-sided post sections, octagonal mast section and upper and lower lantern dimensions.

All framing drawings
Jack A. Sobon

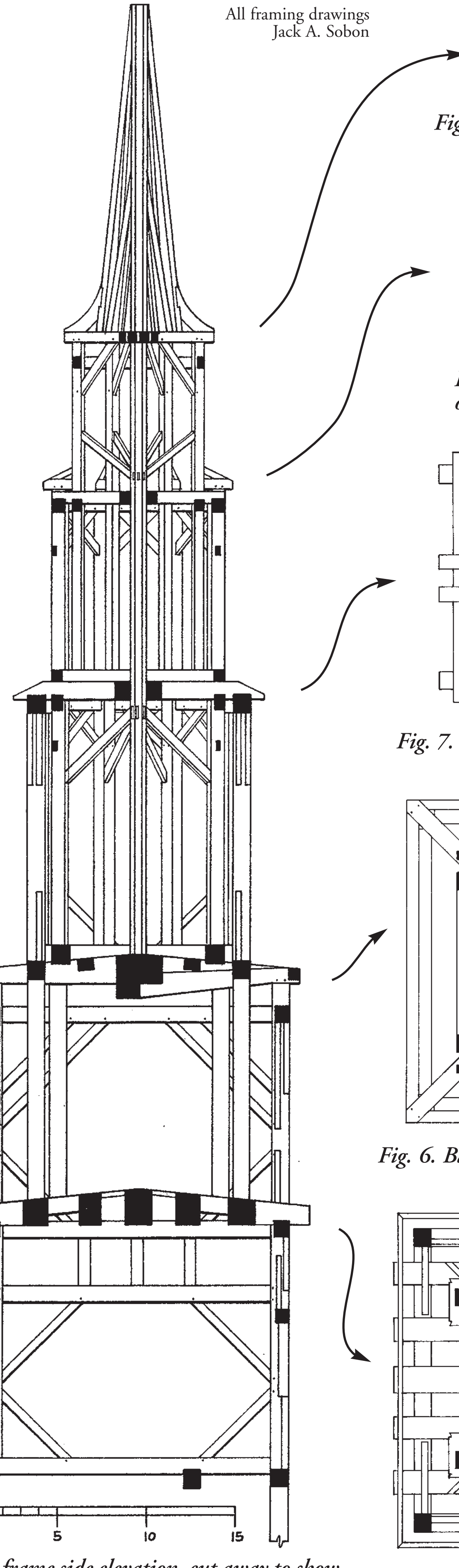


Fig. 4. Steeple frame side elevation, cut away to show original mast. Mast is now refooted one stage higher, at top of clock stage.

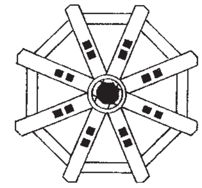


Fig. 9. Base of spire (crab).

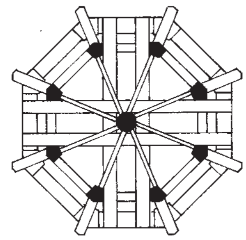


Fig. 8. Base of second octagon (partners).

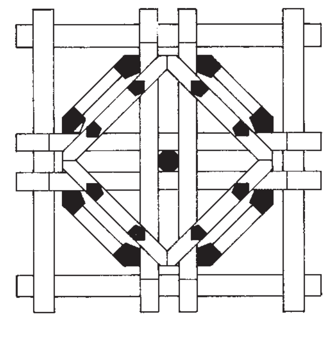


Fig. 7. Base of first octagon (partners).

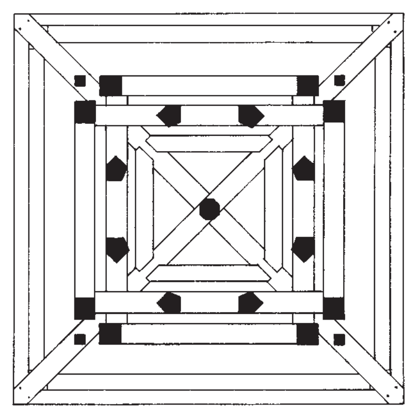


Fig. 6. Base of clock stage, with mast foot.

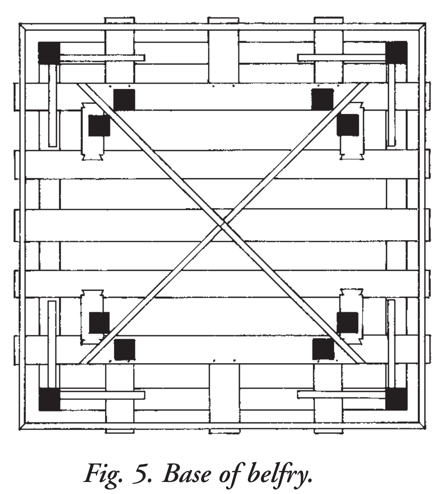


Fig. 5. Base of belfry.

THE CENTRAL MAST. The Middlebury steeple has a tall central mast of oak, originally footed at the top of the belfry and now beginning above the clock stage, that ultimately supports the ornaments and vane at the top of the spire. The mast is octagonal for its entire 53-ft. 2-in. length (as calculated with the aid of Historic American Buildings Survey drawings), and measures 11 in. across the flat faces. It is pierced by 32 mortises accepting bracing and crab timbers and also clasped by double pairs of partner timbers at two different elevations, forming, with the diagonal crib timbers lodged upon them, another sort of octagonal bearing as well.

The mast was originally footed with a tenon on a crossed pair of immense timbers, cambered both top and bottom, forming the roof system over the belfry (Figs. 10–11).

Timbers this size, each cambered to 10x17 at the crossing and one augmented on top by a cambered 10x12, are usually reserved to carry the weight and dynamic loads of a bell, not the lightweight roof over it, so it can be supposed that the framer thought one of two things: first, that the mast might permanently carry the accumulated load of the three stages and spire forming the upper 54 ft. of the wooden structure; or, second, that the mast was to be erected, somehow braced, and used as a lifting rig (or at least a stabilizing axis) for these upper levels.

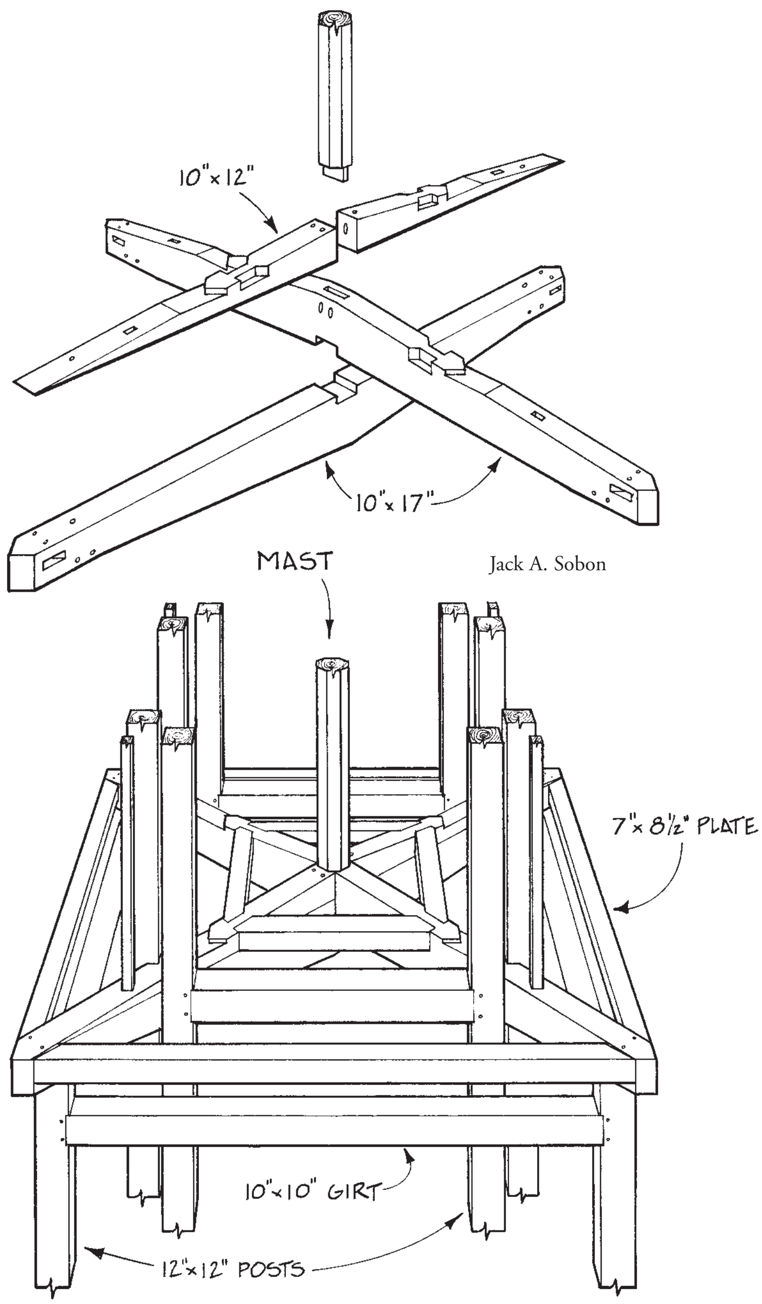
If Fillmore and Crandal believed the first, they were proved wrong by 1853 when the base of the mast was cut off about 9 ft. above its bearing point to make room for the clock shafts. This offcut base segment lies about 3 ft. away from its original mortise, carrying some flooring today. The great number of braces, crabs and partners proved adequate to keeping the mast in place, so that while it isn't pendant (hanging unsupported from the apex, as the mast is in some other steeples), it's no longer footed either, and none the worse for it.

The second possibility, that the mast functioned as a lifting rig for its surrounding framing, and thus temporarily bore great loads, remains a conjecture. The great density and interconnectedness of the framing makes it unlikely that the various frames were brought up whole from within, as is known to have been done elsewhere, for example at the Strafford, Vermont, Meetinghouse (1799) and the Centre Church (1812) in New Haven, Connecticut. At New Haven, we have eyewitness accounts of such a raising and, at Strafford, three out of a set of four gin-pole bases are still in place at the corners of one tower level to carry out the sort of full-stage lifting for which contemporary accounts exist (Lewandoski 6–7).

At Middlebury, however, large pieces and partial frames may have been erected and stabilized by the mast during assembly. A relict gin pole, a single 15-ft. piece of 5-in.-dia. ironwood (hop hornbeam) with an iron-bound top and eye bolt for rigging, left embedded at the level of the clock, suggests that lifting was also being done by something additional or combined with the mast (inset photo). This gin pole may have been attached to the mast as a jib, allowing the rigging to reach out over the side of the tower to snatch loads from below. Square reliefs cut out of horizontal timbers at several upper levels also suggest that individual large timbers were brought up right through the partially completed frame.

Photos Ken Rower

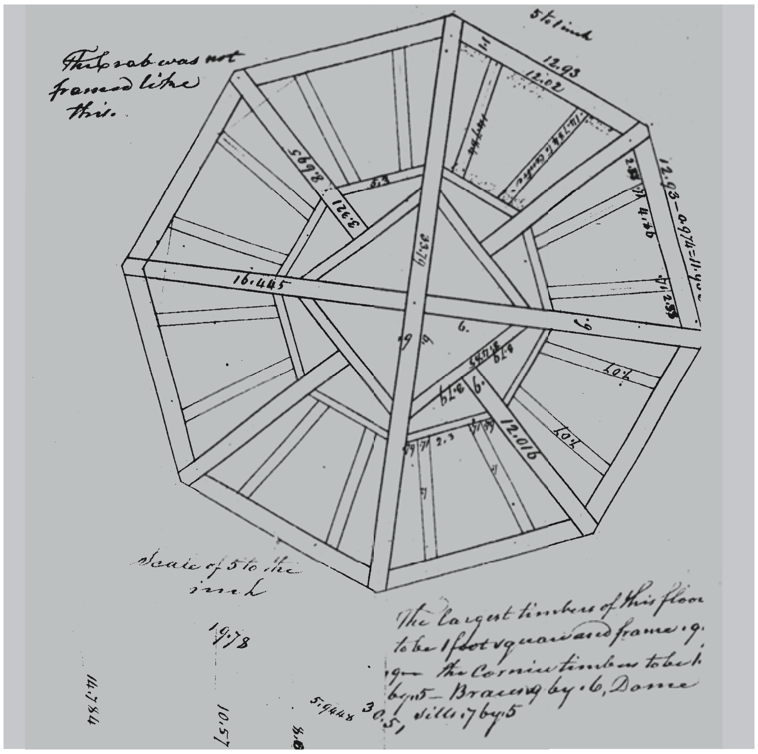
Fig. 10. Deep beams to foot the mast, the latter cut away in 1853 to make way for slender shafting to drive clock faces installed over the windows of steeple's third stage.



Jack A. Sobon

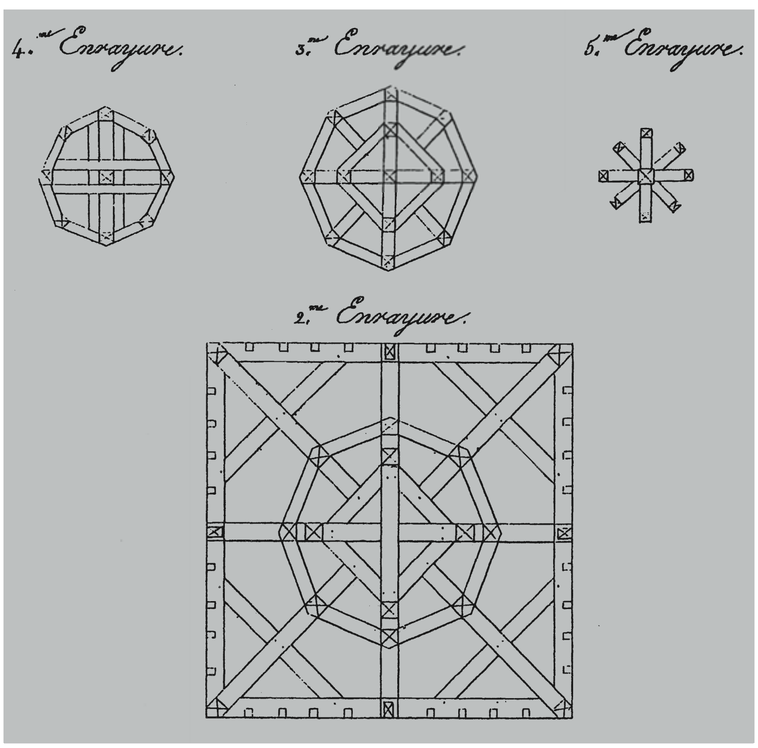
Fig. 11. Original mast foot of massive 10x17 crossing ties notched only 2 in. at lap, with tapered 10x12 packing pieces pinned over one tie and 9x8 braces stiffening the crossing. Posts for first lantern omitted.

THE CRAB. In timber framing, "crab" refers to a horizontal frame with eight legs or regularly spaced points of bearing or tying, flat or slightly cambered, sitting atop the posts of one octagon and supporting the posts or rafters of another. The term has historic credentials. The Burlington, Vermont, framer John Johnson drew and labeled crabs and specified them in his lumber lists for the Orleans County Courthouse (1816) in Irasburg, Vermont, as well as for an immense one, 34 ft. across, for the octagon atop the Centre College building at the University of Vermont in Burlington in 1829 (Fig. 12).



University of Vermont Special Collections

Fig. 12. John Johnson's drawing of a crab nearly 34 ft. in diameter. "The crab was not framed like this," he notes.



École des ponts et chaussées

Fig. 13. "Enrayures" from the second through fourth stages of the Clocher d'Olonne, a tower on an exposed point of the Atlantic coast of France. A pure crab is shown at stage 5, a set of partners at stage 4.

Photos Jan Lewandoski

Fig. 14. Mast foot crab at St. Mary the Virgin at Cleobury-Mortimer.

Robert Smith's St. Peter's Episcopal Church in Freehold, New Jersey (1771), has a typical crab (though we don't know what he called it). In French work, several types of crabs as well as partners were used and illustrated, and called *enrayures*, a term also used for the spokes of a wheel and for a plate system in complex roofing not limited to octagons (Fig. 13).

As long as octagons have needed bearing or tying, some form of crab has been in use. In his surveys of British carpentry, Cecil Hewett doesn't use the term crab but illustrates one exactly like those common in the 18th and 19th centuries in America, with four long legs and four short, in his drawings of the southeast spirelet of Canterbury Cathedral, Kent, which he dates to the 12th century. Hewett uses the term *star* for another sort of eight-legged figure where all the legs radiate from a common center, with the crowded joinery or metalwork that this entails, at Canterbury Cathedral (Hewett 1985, 139). The latter sort of crab is in use at Middlebury.

The oldest wooden spire I have examined, the 13th-century Church of St. Mary the Virgin at Cleobury-Mortimer, Shropshire, England, has an eight-pointed star or crab footing the mast and tying the rafters. Elsewhere in this spire naturally curved timber is used to provide eight points of bearing and tying. St. Mary's octagonal spire has lines of four long spire rafters joined by horizontal girts with a natural 45-degree crank, the projecting mid-sections mortised, providing bearing and a tie for shorter rafters and producing four more arrises for the spire (Figs. 14–15).

Fig. 15. Crooked timber exploited for octagonal spire framing.

At Middlebury, the framers used three different types of structures to support octagons. The first was a crab or star with eight legs radiating out from the mast. This form is usually the weakest since there is not likely to be room in the mast for eight good mortises or, if there is, no room to pin them. At the foot of its eight spire rafters, Middlebury solves this problem ingeniously by dropping four 8x7½ legs into wedged half-dovetail mortises in the mast, while the other four double-miter between these and tenon horizontally into the sides of the dovetailed legs, to which they are pinned. These crab legs do not align with the flats of the octagonal mast but are centered on its arrises (Figs. 17–18).

The second method was a bi-level sort of crab based upon two, or two pairs of, timbers crossing the octagon at right angles to each other and another square of sleepers or crib timbers lodged diagonally on top of these. The upper level carries the eight posts. Compress the two levels into one and you have a crab. This type of crab is found in Middlebury over the belfry at the massive base for the mast, on which are lodged the sleepers for the lower octagon frame (Fig. 11), and found again at the bottom of the upper octagon, where short ties connect the tops of the posts of the lower octagon with the midheights of the posts of the upper octagon and parallel sets of ring girts connect the respective post sets (Fig. 16).

Photos Ken Rower

Fig. 17. Seen from below, intricate joinery at base of spire connects legs of crab to mast, which continues on to carry weathervane.

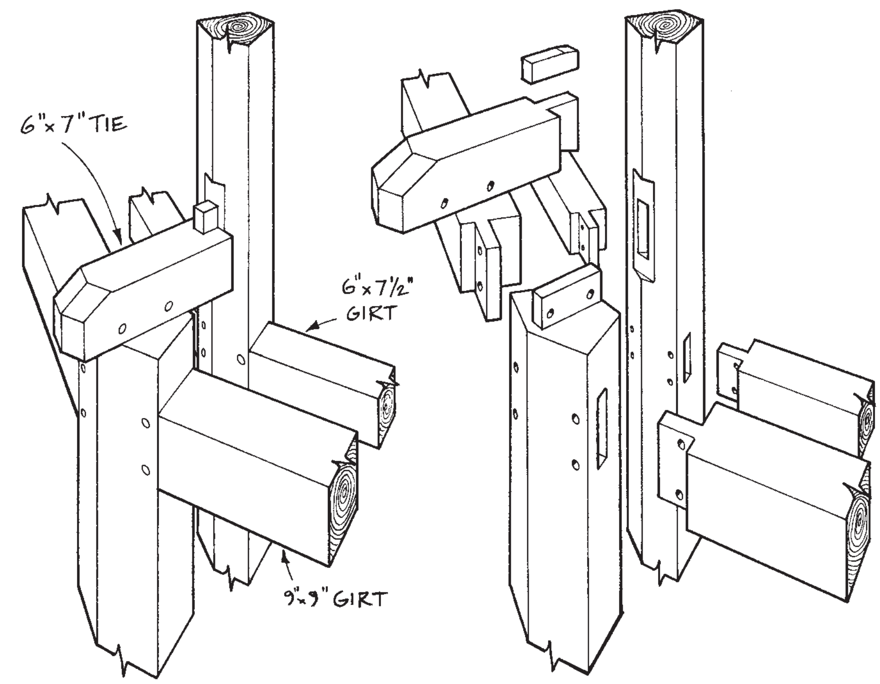
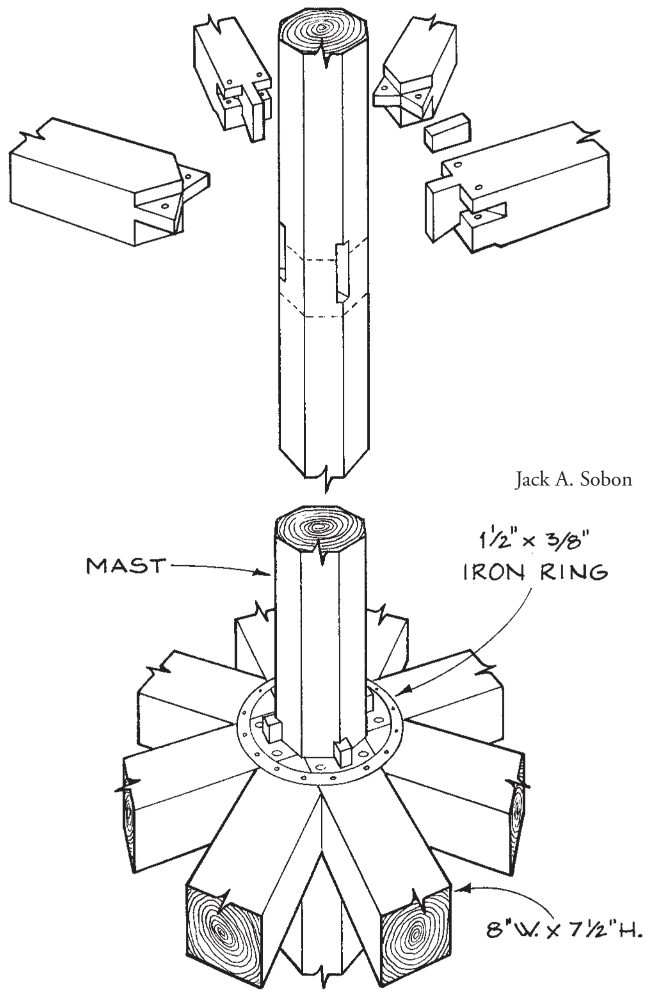


Fig. 16. Short ties connect posts of lower and upper lanterns using wedged dovetail joint. Mast partners omitted for clarity.



Jack A. Sobon

Fig. 18. Crab at base of spire. Four legs join mast with wedged half dovetails, remaining four join first four via pinned triangular tenons in open mortises. Nailed iron ring completes the job.

The third type of support is found at the bottom of the clock stage (or top of belfry), which has eight corner posts but expresses itself on the exterior as a square (Figs. 6 and 11). These 12x12x28 posts begin 12 ft. below on the mighty bell deck framing, where five pine sleepers as large as 18x22 span the 17-ft.-square tower. Four of the posts land directly on sleepers and four on short dovetailed 12x12 connectors between sleepers (Fig. 5). Slightly separated in each pair and flanking each corner as seen in Fig. 21, the posts clasp the diagonal crossing timbers of the belfry roof as they pass and support large mast partners at their own top-plate level.

This immense expenditure of timber and mass may have been used to anchor and clasp the mast that was by some powerful rigging erected within it, the mast finally projecting out almost 40 ft. above the partners at the top of the clock stage. The mast could then be used to lift the framing of the two octagonal stages and the spire by means of block and tackle.

THE PARTNERS. In naval architecture, partners run athwartships in pairs and clasp the masts to keep them upright. The mast itself is footed as well, somewhere deep in the vessel. Partners that clasp the masts of church steeples are framed similarly. Church spires, many of which have masts within them, may appear to spring from the top of the highest lantern or belfry, but this is usually not the case. Rather, the typical spire rafters are tenoned or spiked to facets (usually eight) at the top of the mast. The rafters then foot them-

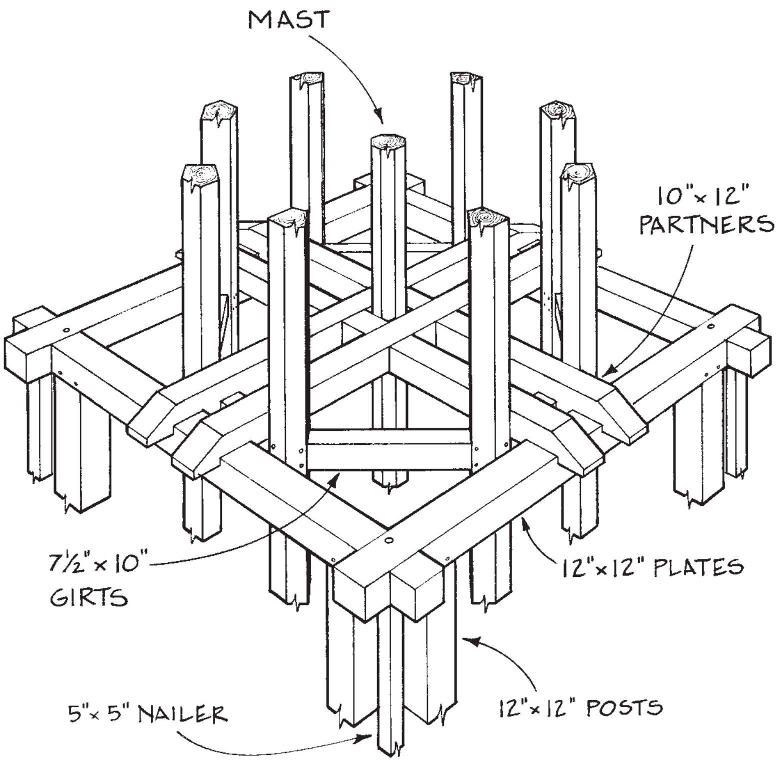


Fig. 19. Framing of partners at top of clock stage. Mast partners tie across top plates and restrain octagon posts rising through them. Plates are halved and pinned and a 5x5 nailer fills out the corner. Inner octagon (second lantern) posts and base omitted for clarity.

Fig. 20. Viewed from below, upbraces from rising lower octagon posts assist partners at top of clock stage.

Fig. 21. Eight 12x12x28 posts in cater-corner pairs rise from the belfry roof to the top of the clock stage. Plan views in Figs. 5–6.

selves on a crab or octagonal plate, or a square plate level at the base of the visible spire. These rafters may also attach to the mast with nailers or mortised girts and bracing on their way down. The steeple mast itself may descend another 10 to 30 ft., concealed within the lower stages of the steeple and stabilized by partners, which run side to side between the major framing members and half lap each other at the middle, leaving a square space in which the mast is clasped. Consequently, the tall and slender mast and spire are restrained by the rigidity and mass of the bulkier lower stages. At Middlebury, two levels of partners—one at the top of the clock stage (base of first octagon) and the other at the top of the first octagon (base of second octagon)—are not designed to tenon into posts or arrive at a panel point, nor to be expressed in the exterior finished form of the steeple, but instead are opportunistically attached to the framing of the two surrounding telescoping stages and correctly spaced to clasp the mast (Figs. 19 –20).

Though it represents excellent practice in a building designed to endure indefinitely, partnering a spire mast as if it were a ship's mast carrying sail would be undertaken only by the most conservative of framers. Sails are designed to invite tremendous wind pressure; an octagonal spire, close in form to a cone, experiences relatively little. Many spires are built without masts; either the rafters themselves start some distance lower in the steeple stages, or they spring from the top of a belfry where they are usually bound with long iron rods anchored deep within the steeple or with metal dogs or straps to a heavy plate and buttressed by a skirting roof. From a framer's point of view, the functions of a mast may be multiple: part rigid restraint, part inward moving of the spire's center of gravity, part structural focus for framing the upper stages in a unified fashion. The mast also may be an aid in erecting the spire if the latter's parts come up from below and within. If the mast is not partnered or footed, it may provide a mysterious pendulum action to stabilize the tower. (Except in very tall and large spires, the partners may have more purpose during erection than during the life of the spire.)

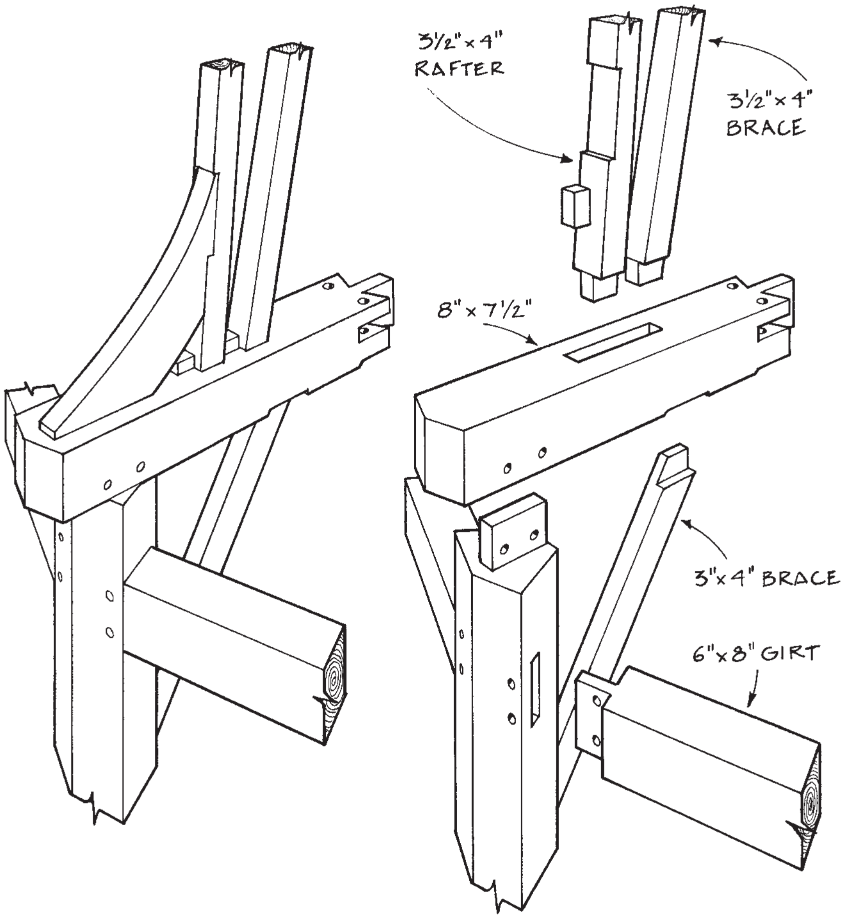


Fig. 22. One-eighth of spire base and roof framing. (Plan view Fig. 9.) Each crab leg supports a rafter and a brace both up to the mast and down to the octagon post. Wedges allow fine-tuning.

Photos Ken Rower

Fig. 23. View straight up into spire. Curved pine roof boards at top, oak mast at center, oak braces and spire rafters at left and right.

At Middlebury, however, the ambitious goal was rigidity. The partners, clasping the mast and then engaging laps in the girts and plate level of the two surrounding telescoped stages, are bound down into these lap joints by the crib timbers of the next octagon stage, carrying the many thousands of pounds of weight of the 30 or 50 ft. of steeple, respectively, remaining above them.

Even the spire, a 19-ft. tall tapering octagon with low wind resistance, centered on a stout oak mast virtually buried in 34 ft. of timber work below, is framed for rigidity. The spire rafters and an inner set of rising braces (half the rafter height and with a different slope) share a common wedged mortise on the tie beams of the spire crab. The curving skirt of the spire is framed of 3-in. plank let into rather than tacked to the rafters, another form of buttressing (Figs. 18 and 22).

I HAVE emphasized Middlebury's rigidity through this discussion because its steeple is indeed rigid relative to the other 100 or so wooden steeples I have examined in the last 30 years, and reflects the apparent intentions of the designer and builder. While surveying the steeple, even with our shoulders pressed up against the spire base (about as high as average adults could go), three persons moving in unison to produce sway in Middlebury's massive interlocked timber construction were rewarded with very little, far less than the stomach-unsettling amounts that can be produced easily in most tall wooden steeples. But being slender and framed of timber allows even this steeple to be somewhat flexible as well, with the benefits that swaying rather than breaking convey, but rather less so than most other wooden steeple designs.

The notable steeple at the Federated Church (1832) in nearby Castleton, Vermont, is a contrary but also successful design. Almost identical in height to Middlebury, and with even deeper telescoping onto lodged crib timbers, Castleton's elements are so little interconnected that they could be lifted apart for repair into three discrete units, each 30 to 50 ft. tall, with only the dismantling of flashing and lightweight nailed skirting roofs. The telescoping at Castleton is remarkably deep, with the belfry columns beginning 28 ft. below where they emerge from the tower. Likewise at the Congregational Church (1861) in Stowe, Vermont: there the feet of the four sets of paired columns of the belfry originate within inches of the bases of the 22-ft. tower posts and rise an additional 16 ft. above them. However, the only connections between the inserted stages at Castleton, Stowe and many other late-18th-century and 19th-century steeples are the cornices and the boarding and the small, usually nailed, rafters of the skirting roofs. Even at their bases, the columns of the various stages are tenoned into sleeper timbers that are merely lodged, not framed into or mechanically connected to the timbers they rest upon. (This last is true at Middlebury as well for the upper stages.)

At Stowe, the first three stages all clasp the 100-ft. tall central mast with partner timbers, and thus have an indirect connection to each other, but their purpose is to counterpoise the tall mast and spire, not to link to each other. Middlebury's stages are deeply telescoped, but the frames of the interpenetrated stages are connected to each other and the mast with substantial framing and joinery every few feet. At four locations, joinery attached to the central mast connects rigidly with the plates and girts of two surrounding telescoping stages.

Fig. 24. A globe arch centered over the audience room at Middlebury requires special roof framing adaptations.

Fig. 25. Multiply braced queenpost trusses run the long way in the attic flanking the dome, to account for absent transverse kingpost truss.

MIDDLEBURY'S TRUSSED ROOF. Though our subject is steeples, it would not do to leave the reader curious about the trussed roof system of this 59-ft.-wide church. The trusses are impressive and adopt several forms to accommodate the 32-ft.-dia. globe arch (dome) in the center of the main room (Fig. 24), a feature the architect Lavius Fillmore also included at his meetinghouse at Bennington, Vermont (1805), and framed similarly.

The truss work at Middlebury does not rival the density or complexity of its steeple frame, like Bennington's supported at the front on sleepers tenoned to continuous posts rising from the foundation. The Middlebury kingpost trusses are almost identical to those found at Bennington and at Fillmore's Norwichtown, Connecticut, Meetinghouse (1801), and similar to those (also assisted by colossal columns) found in his East Haddam, Connecticut, Congregational Church (1794), where many of Middlebury's interior design elements appear also (Kelly, 109-117, 119-128).

The roof frame at Middlebury is formed of kingpost trusses on regular centers, with one exception, where the dome projects into the middle of the attic beyond the third interior truss from the front. In this space approaching 40 ft. long, where two transverse trusses are expected, there is only one, a raised-bottom-chord kingpost truss centered, according to HABS drawings, at 18 ft. 9 in. between the third and fifth trusses. The chord is raised to sit above the top of the dome.

However, truncated tie beams are still found on the regular truss centers, as supporting structure for the ceiling and the dome, and these in turn are suspended from curiously framed longitudinal queenpost trusses with multiple external braces on either side of the dome (Fig. 25).

The 10x10 queenposts hang directly over these truncated tie beams, and the main braces of these trusses are quadripartite: four vertically sawn oak timbers fanning out to bear, in wedged mortises, on the bottom chords of the adjacent third and fifth truss. From each queenpost a pair of main braces drops directly to the chords of the third and fifth trusses just over their supports by the colossal columns. The efficacy of the other two braces, which drop to unsupported points on the chord, is less clear, unless they act to stabilize the lightly built truss laterally.

For a span as large as Middlebury's, a kingpost truss without prince posts would be only marginally adequate, but the colossal columns that rise to the truss chords and the longitudinal queenpost trusses resolve any problems, and there is little sag in the roof or ceiling. —Jan Lewandoski

Additional research for this article was contributed by Ed Levin, Ken Rower and Jack A. Sobon.

BIBLIOGRAPHY

Andres, G., "Lavius Fillmore and the Federal Style Meeting House," in *New England Meeting House and Church: 1630–1850,* ed. P. Benes, Boston, 1980.

Freeman, S.A., *The Congregational Church of Middlebury, Vermont,* Middlebury, 1990.

Gwilt, J., *The Encyclopaedia of Architecture,* London, 1867.

Hammond, J., "The 18th Century Church Designs of Robert Smith," TF 73, September 2004.

Hewett, C. E., *Church Carpentry,* London, 1982.

—, *English Cathedral and Monastic Carpentry,* Chichester, 1985.

Historic American Buildings Survey, Middlebury, Vermont, Vt-11.

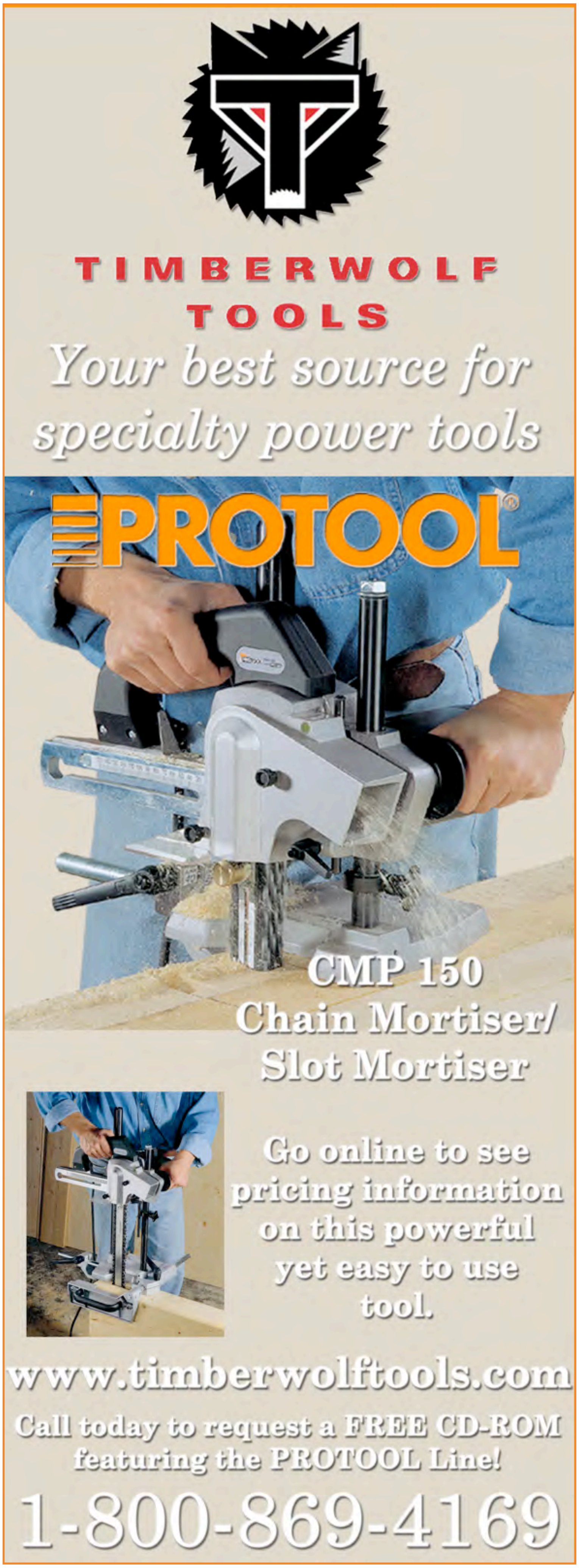
Isham, N., *The Meeting House of the First Baptist Church in Providence,* Providence, 1925.

Johnson, J., Unpublished manuscript collection, University of Vermont Special Collections, Burlington, Vt.

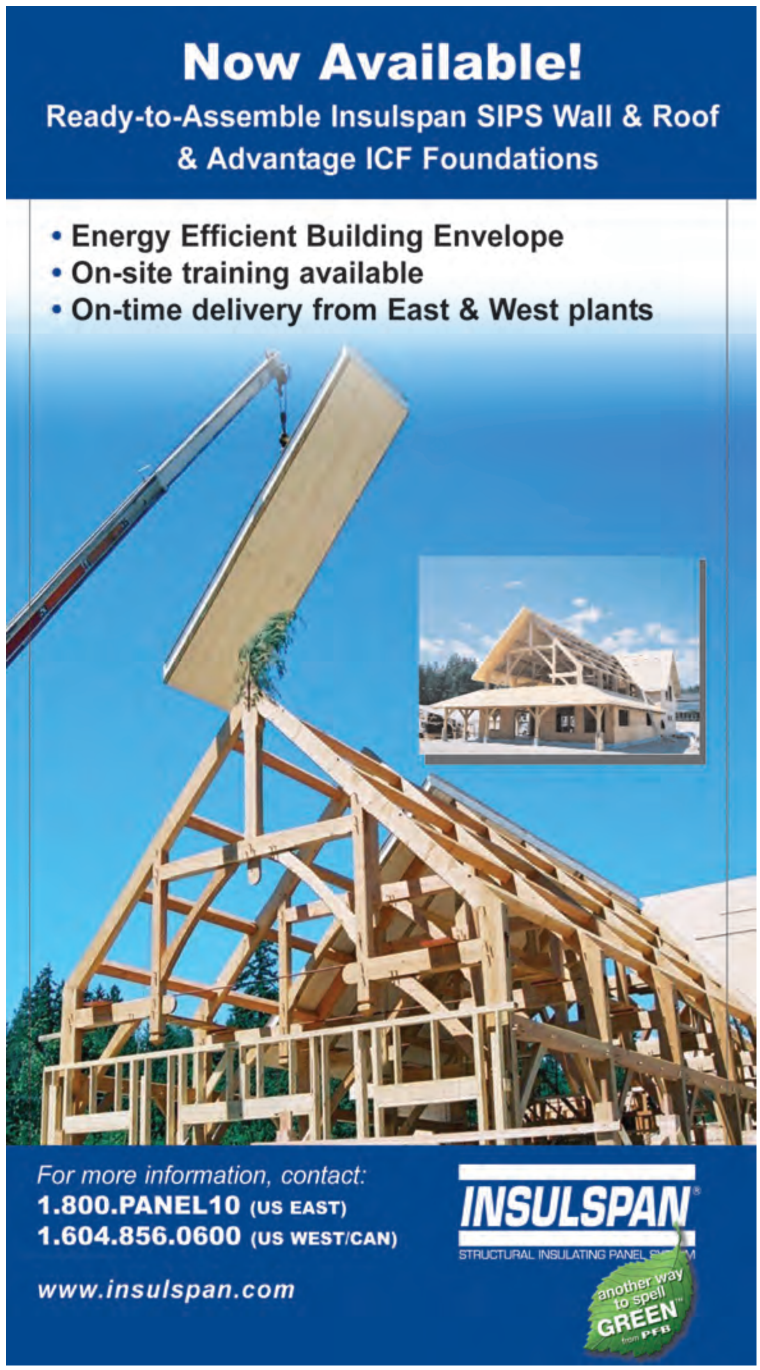
Kelly, J. F., *Early Connecticut Meeting Houses,* 2 vol., N.Y., 1948.

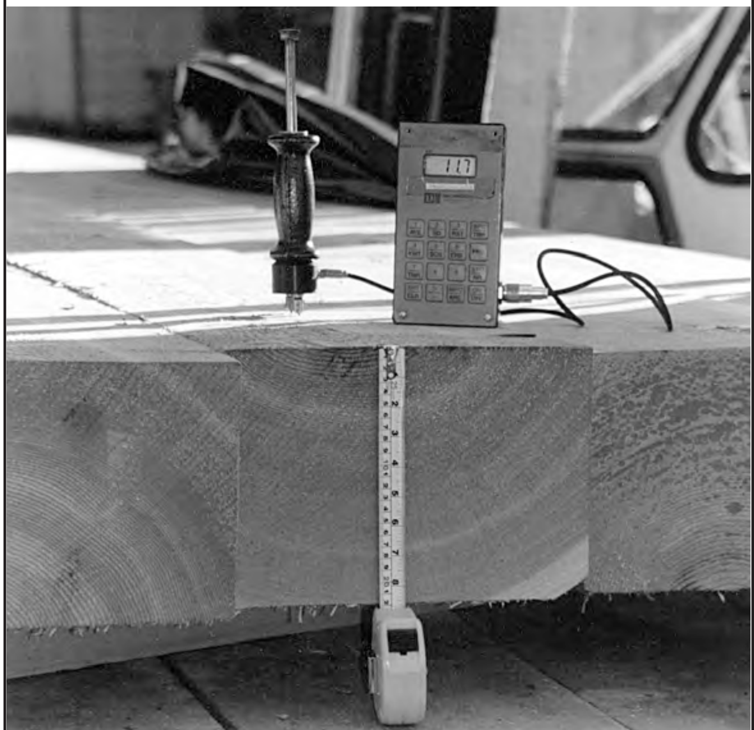
Lewandoski, J., "The Erection of Church Steeples," TF 36, June 1995.

Recueil de 239 Dessins relatif à l'Art de l'Ingénieur, École royale des Ponts et Chaussées, Paris, 1825.


TIMBERWOLF
TOOLS
Your best source for
specialty power tools
PROTOOL
CMP 150
Chain Mortiser/
Slot Mortiser
Go online to see
pricing information
on this powerful
yet easy to use
tool.
www.timberwolftools.com
Call today to request a FREE CD-ROM
featuring the PROTOOL Line!
1-800-869-4169


TIMBERLINX®
...the ultimate timber connector
TIMBERLINX can be used in any joint
wood to wood, wood to concrete, wood to steel
Impossible joints become possible
Fast, cost-effective, certified for tension and shear
Contact: Michael Preston
Neil Maclean
1-877-900-3111
timberlinx@sympatico.ca
www.timberlinx.com


Now Available!
Ready-to-Assemble Insulspan SIPS Wall & Roof
& Advantage ICF Foundations
• Energy Efficient Building Envelope
• On-site training available
• On-time delivery from East & West plants
For more information, contact:
1.800.PANEL10 (US EAST)
1.604.856.0600 (US WEST/CAN)
www.insulspan.com
INSULSPAN®
another way to spell GREEN™



PUBLISHED BY
THE TIMBER FRAMERS GUILD
PO BOX 60, BECKET, MA 01223

NONPROFIT ORG.
U.S. POSTAGE
PAID
BARRE, VT
PERMIT NO. 222