8 Recommendations

The recommendations contained in this report are based solely on the BPAT's observations and conclusions. These recommendations are intended to facilitate future personal and property protection from tornadic wind events.

8.1 General Recommendations

The May 3, 1999, tornadoes were disastrous in terms of lives lost and property destroyed, but this disaster comes the opportunity to reflect on what is important in peoples' lives. As a result of these reflections, Oklahoma and Kansas communities can commit to planning for future tornadoes through promoting sustainable construction and tornado-resistant communities.

As the people of Oklahoma and Kansas rebuild their lives, homes, and businesses and plan for future economic development, there are several ways they can reduce the effects of future tornadoes, including:

- Design buildings to the most current building codes and engineering standards that provide greater protection against tornado-generated winds or, at a minimum, improve compliance with existing codes.
- Provide safe refuge in the event of a strong or violent wind storm or tornado in the form of engineered shelters.

More specific recommendations are included in the following subsections. Mitigating future losses, however, will not be accomplished by simply reading this report; mitigation is achieved when a community actively seeks and applies methods and approaches that lessen the degree of damage, injuries, and loss of life that may be sustained from future tornadoes.

8.2 Property Protection

Property protection recommendations have been divided into subsections on residential and non-residential building considerations, codes and regulations, and voluntary actions.

8.2.1 Residential and Non-Residential Buildings

Proper construction techniques and materials must be incorporated into the construction of buildings to reduce their vulnerability to damage during moderately high wind events. Existing construction techniques proven to minimize damage in wind-prone areas such as coastal areas subject to hurricanes are not always being utilized in areas that are subject to tornadoes. Construction must be regulated and inspected to ensure that buildings meet the most current model building code requirements.

It is recommended that, for engineered buildings, the engineer review structural connections to ensure adequate capacity for design uplift and lateral loads that may be in excess of loads based on the building codes currently in effect. To address the issues of construction that may be mitigated to improve building performance, the following recommendations are provided:

- Sheathing areas of discontinuity should be fastened in a manner that will resist design uplift forces with a factor of safety over the design wind pressure stipulated in applicable building codes and standards. Some current building codes reflect an increased fastener size intended to address high wind areas.
- The brick masonry industry should consider re-evaluating attachment criteria of brick veneer, specifically regarding product usage. Greater emphasis should be given to code compliance for the bond between the mortar and brick ties, the mortar and the brick, and to the spacing of brick ties.
- Garage doors are an extremely important residential building component. Failure of these doors led to catastrophic progressive failures of primary structural systems that could have been significantly reduced in areas other than those impacted by violent and strong tornado vortices. New garage doors should be manufactured to comply with design wind loads using a safety factor of 2. Retrofits should be made to improve the wind resistance of existing garage doors, particularly double-wide garage doors. Figures 8-1, 8-2, and 8-3 present retrofit measures that have been successfully implemented in Florida after Hurricane Andrew. Use of these retrofits and installation of new reinforced doors should better resist wind forces and, as a result, reduce the type of roof and wall damage that was observed in homes that experienced garage door failures.

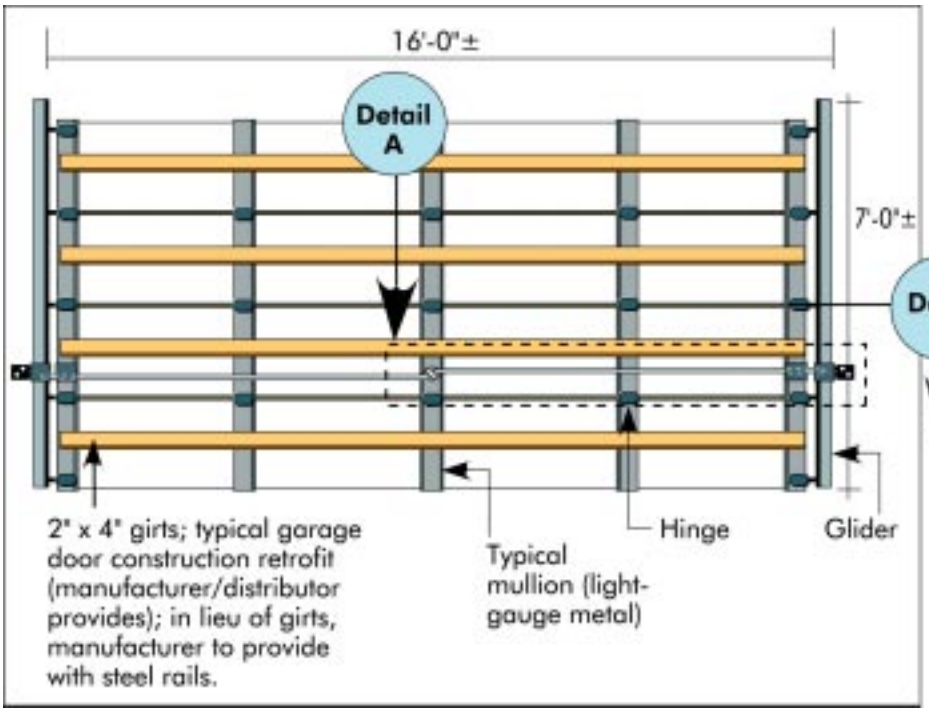


FIGURE 8-1: Typical double-wide garage door elevation.

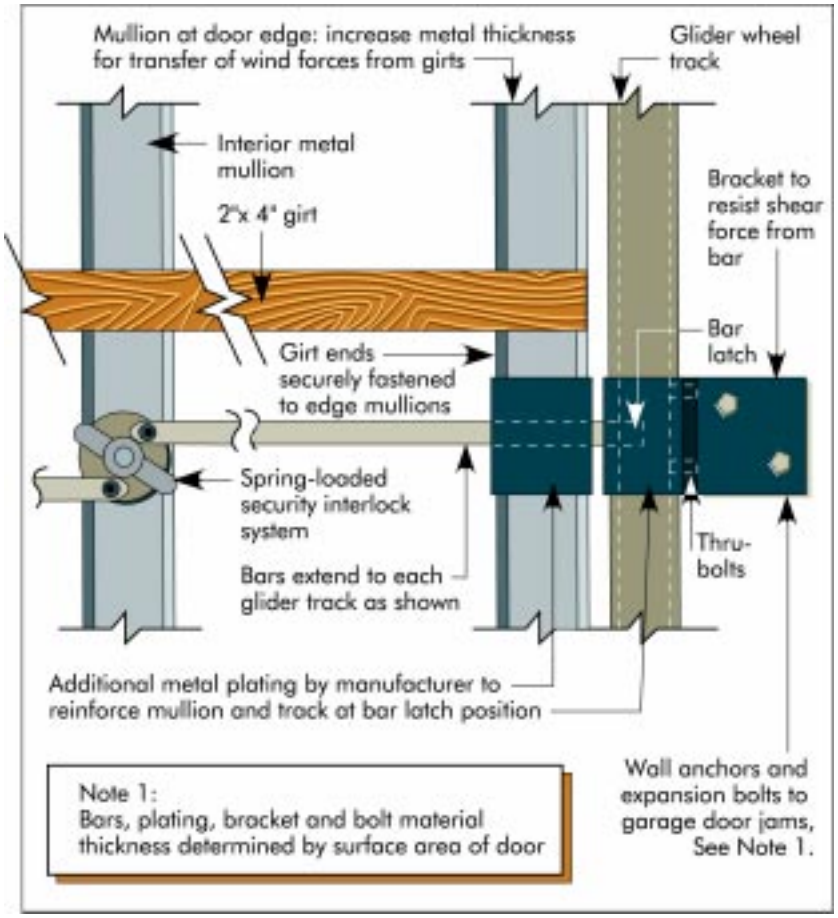


FIGURE 8-2: Detail A from Figures 8-1 and 4-19. Recommended reinforced horizontal latch system for garage door.

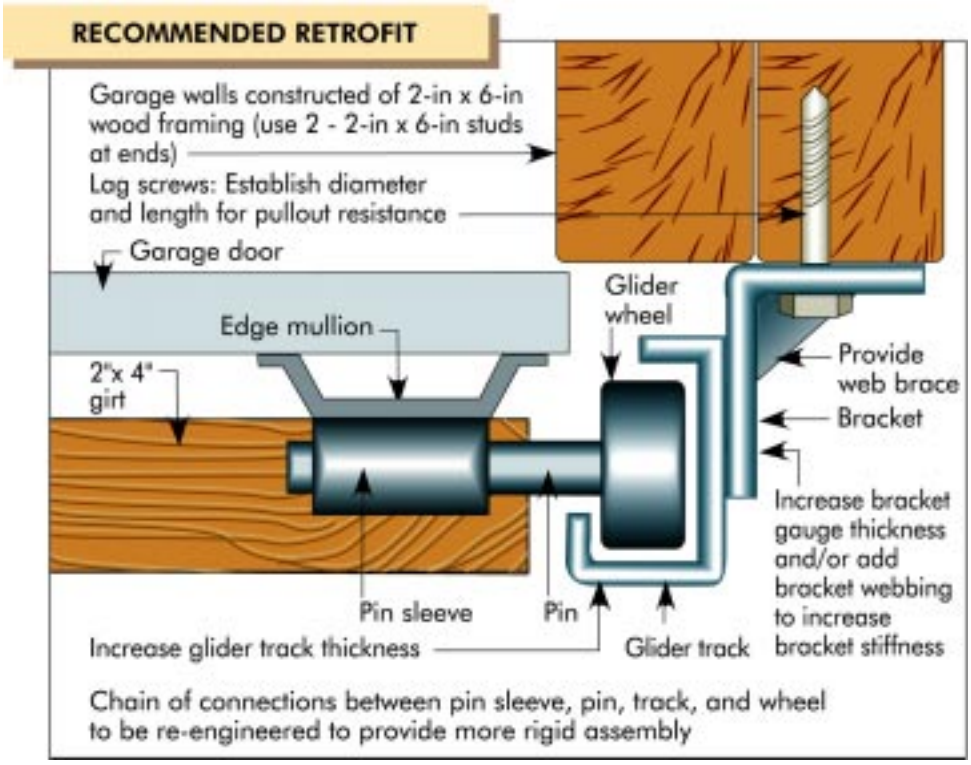


FIGURE 8-3: Detail B from Figures 8-1 and 4-19 illustrating recommended improvements to the garage door track.

- The Federal Government (HUD) should review its standards and enforcement program in an effort to improve the performance of manufactured homes in moderately high wind events, such as in inflow areas of strong to violent tornadoes and the vortices of weak tornadoes. Specifically, the capacity of anchoring and strapping equipment and systems needs to be evaluated to eliminate the discontinuity between the Federal standard and the state and local installation and enforcement process.
- Consideration should be given to permanently connecting the manufactured home unit to its foundation. The BPAT observed newer double-wide manufactured homes on permanent foundations and did not see significant differences in damage between these manufactured homes on permanent foundations and conventionally built houses. The double-wide manufactured homes on permanent foundations performed better than both double-wide and single-width units on non-permanent foundations.
- For non-residential buildings, the BPAT recommends using threaded fasteners to attach metal decking to itself and to supporting frames. In many of the roof system failures observed by the BPAT, welds were insufficient to carry loads and weld failures were common.

- To reduce the number of windborne missiles generated from roofs on essential facilities (e.g., hospitals) and buildings such as schools, aggregate and paver roof surfacing should not be used.
- Enhanced wind design for the roof coverings on essential facilities should be considered for those facilities located in tornado-prone areas.
- When used in areas with a high probability of being hit by a tornado, reinforced concrete and partially reinforced masonry should have adequate ties to foundations and roofs. Ties between concrete and other materials should be made with drilled-in fasteners or cast-in-place fasteners (Figure 8-4).
- Diaphragm action to resist shear forces must be maintained and reinforcement must be properly placed in concrete and masonry walls to reduce the possibility of collapse. Masonry walls should be engineered and constructed to support the specific architecture of the building (i.e., exterior wall panels, parapets, and decorative finishes).

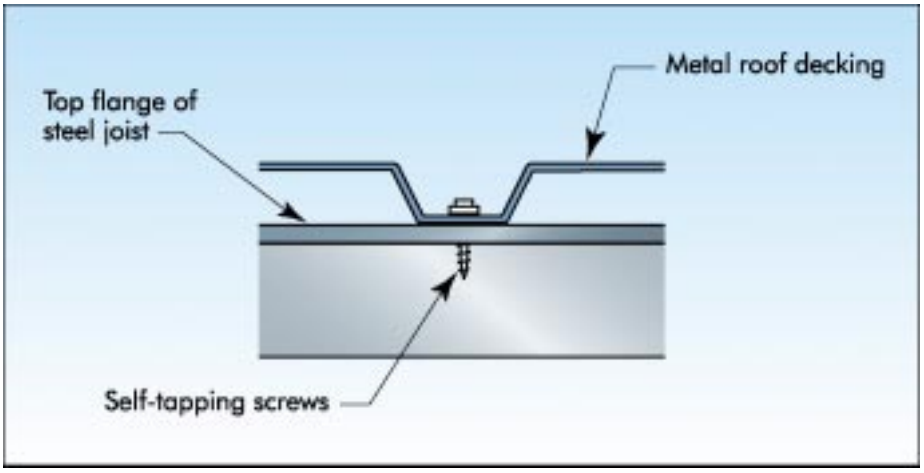


FIGURE 8-4: Illustration of a proper screw-type or drilled-in connection.

- Precast concrete buildings should have anchors to prevent the uplift of hollow core planks and other precast elements. Better performance would have been obtained if drilled-in expansion anchors or thru-bolts had been used to attach the walls to the floors. Use of powder-driven anchors to attach bottom plates of walls to concrete should be avoided unless they are very closely spaced to achieve sufficient pull-out resistance.
- A brick veneer wall system should be designed as a "stand alone" system or construction practices for brick veneer need

to be improved and changed so that a flexible connection between the framed wall and the veneer does not result.

- Ring or screw-shank nails are recommended to fasten brick ties to increase nail pull-out resistance.
- In areas subjected to high winds from either tornadoes or hurricanes, the BPAT recommends that for masonry chimneys that extend more than 6 feet above the roof or have a width of 40 inches or more, continuous vertical reinforcing steel be placed in the corners to provide greater resistance to wind loads. This reinforcing steel should be placed either to the requirements of the 1995 CABO One-and Two- Family Dwelling Code, Table 1003.2, Requirements for Masonry Fireplaces and Chimneys, for seismic zones 3 and 4 or to the requirements of the masonry fireplace provisions of the International Residential Code (IRC) when it becomes available in February 2000.
- Architectural features should be appropriately designed, manufactured, and installed to minimize the creation of windborne debris. To accomplish this, the local community may want to further regulate these features to ensure a reduction in potential debris materials.
- The installation of laminated glass in essential facilities should be considered because of the substantial protection that it offers from modest-energy windborne missiles. As a minimum standard, testing should be conducted in accordance with ASTM E 1886, based on load criteria given in ASTM E 1996.

8.2.2 Codes and Regulations, Adoption and Enforcement

To better address structural and architectural issues related to moderately high wind events, state and local governments should consider adopting the most current edition of a model building code. Other recommendations related to building codes and enforcement are provided below:

- The International Building Code (IBC) and the International Residential Code (IRC) should be adopted upon their release in February 2000. Although these codes do not directly address the threat of tornadoes, they address wind load issues using ASCE 7-98 for both non-residential and residential construction, respectively. Use of these codes in conjunction with ASCE 7-98 will reduce future losses from moderately high wind loads such as those associated with many tornadoes.

- As an interim step to adoting the IBC, Cities and appropriate local governments should adopt the 1997 UBC, the 1996 NBC, or the 1997 SBC, as the local building code as an interim step to adopting the IBC and IRC. Amendments that require calculation of wind loads via ASCE 7-98 should also be adopted. Currently, the 1997 UBC and 1996 NBC reference ACSE 7-95, but allow their own UBC/NBC methods to be used. It is important to note that wind calculations from the building code methods may result in lower loads than calculations from ASCE 7-95 for certain buildings and typically for components and cladding systems.
- As an interim step to adopting the IRC, State and local governments should adopt the 1995 edition of the CABO One- and Two-Family Dwelling Code for jurisdictions using previous editions of this code or having no residential code in place. This will provide some guidance for designing for wind loads.
- Greater emphasis should be given to code compliance, particularly for wall and roof covering wind loads and resistance. Homebuilders and code enforcement agencies should consider developing an active education and outreach program with contractors to emphasize the importance of code compliance for wind resistance.

8.2.3 Voluntary Actions

There are a number of voluntary actions that can be undertaken to reduce the risk of property damage in inflow areas of strong and violent tornadoes and in weak tornado vortices. Some of these are included in the following recommendations and are further illustrated in Figures 8-5 through 8-12.

- To improve tornado resistance, existing hurricane-resistant technologies (e.g., straps, clips, etc.) should be used to protect individuals, their property, and the buildings themselves."
- The design of wood frame buildings should utilize connection devices such as anchors, clips, and straps to provide a continuous load path for all loads: gravity, uplift, and lateral.
- Simple roof geometries (e.g., hip and gable roofs with no dormers) should be used to simply construction and reduce uplift loads.
- Similarly, other building types should utilize connection devices that that provide a continuous load path for all loads: gravity, uplift, and lateral.

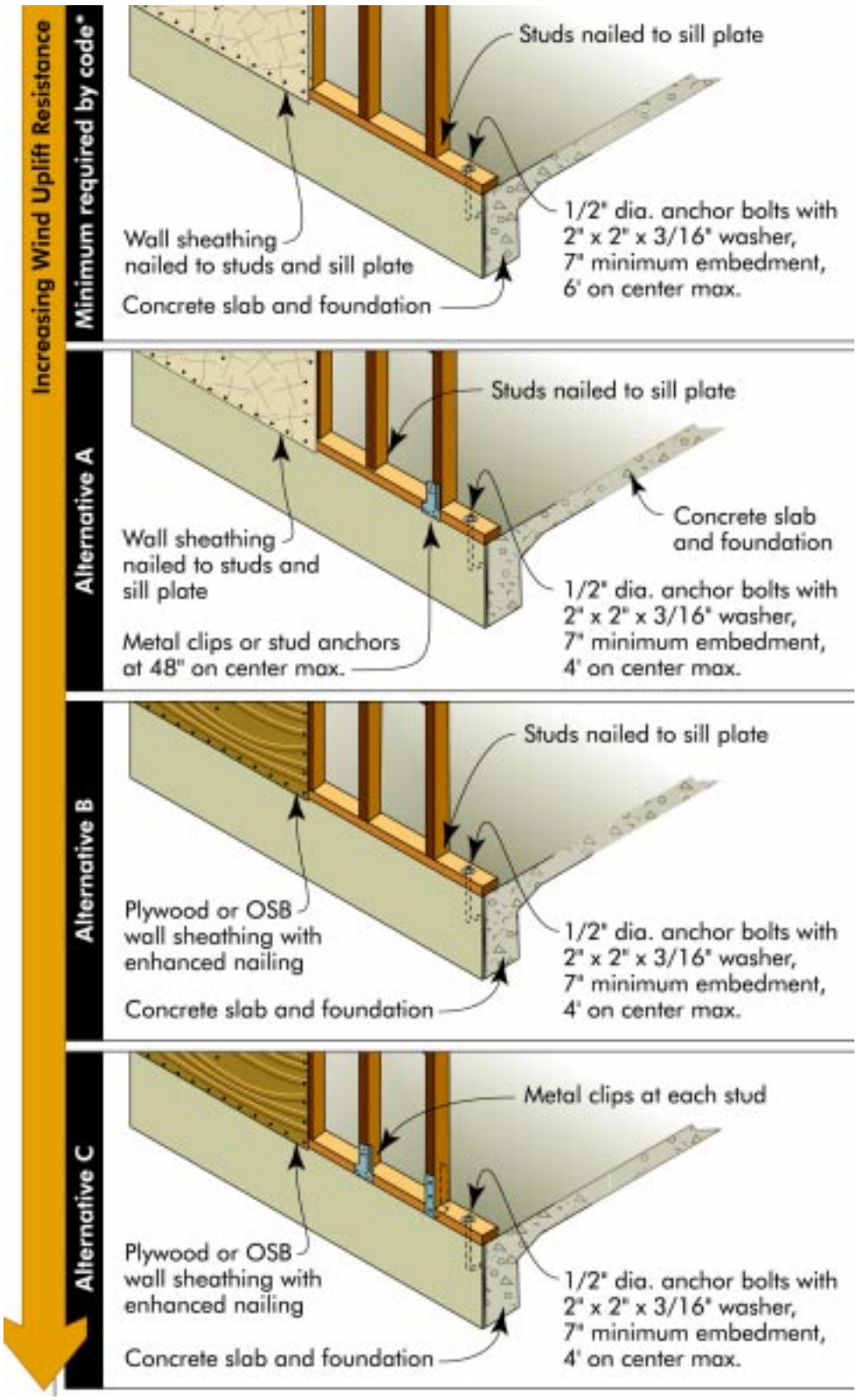


FIGURE 8-5: Illustrations of proper connections of wood frame construction to foundation slabs and walls. The first detail illustrates the minimum connection that should be used in areas with basic wind speeds not exceeding 90 mph peak gust. Alterations A-C illustrate connections that provide increasingly greater uplift resistance. * 1995 CABO One- and Two-Family Dwelling Code.

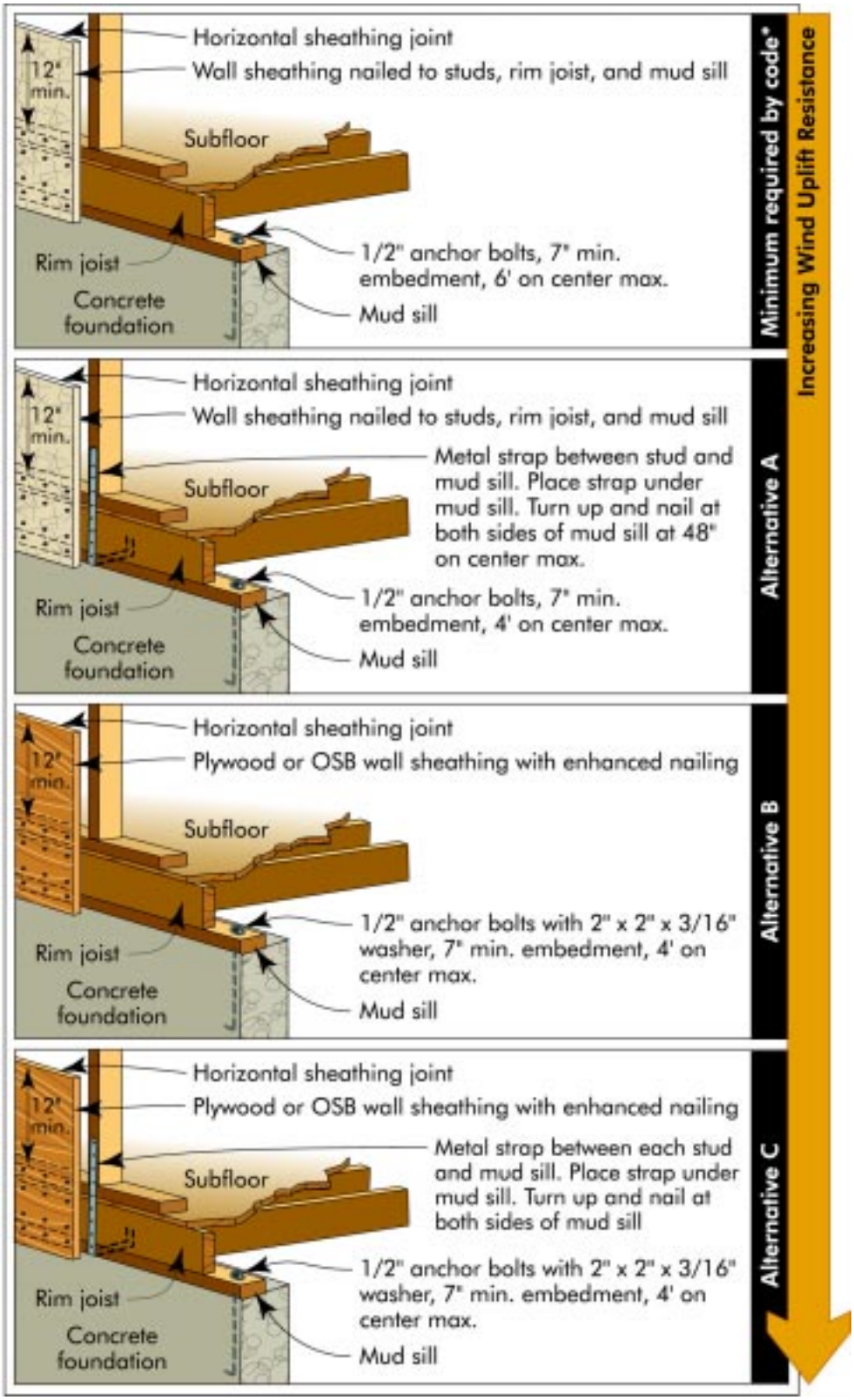


FIGURE 8-6: Wall connections at crawl space foundations. The first detail illustrates the minimum connection that should be used in areas with basic wind speeds not exceeding 90 mph peak gust. Alterations A-C illustrate connections that provide increasingly greater uplift resistance. * 1995 CABO One- and Two-Family Dwelling Code.

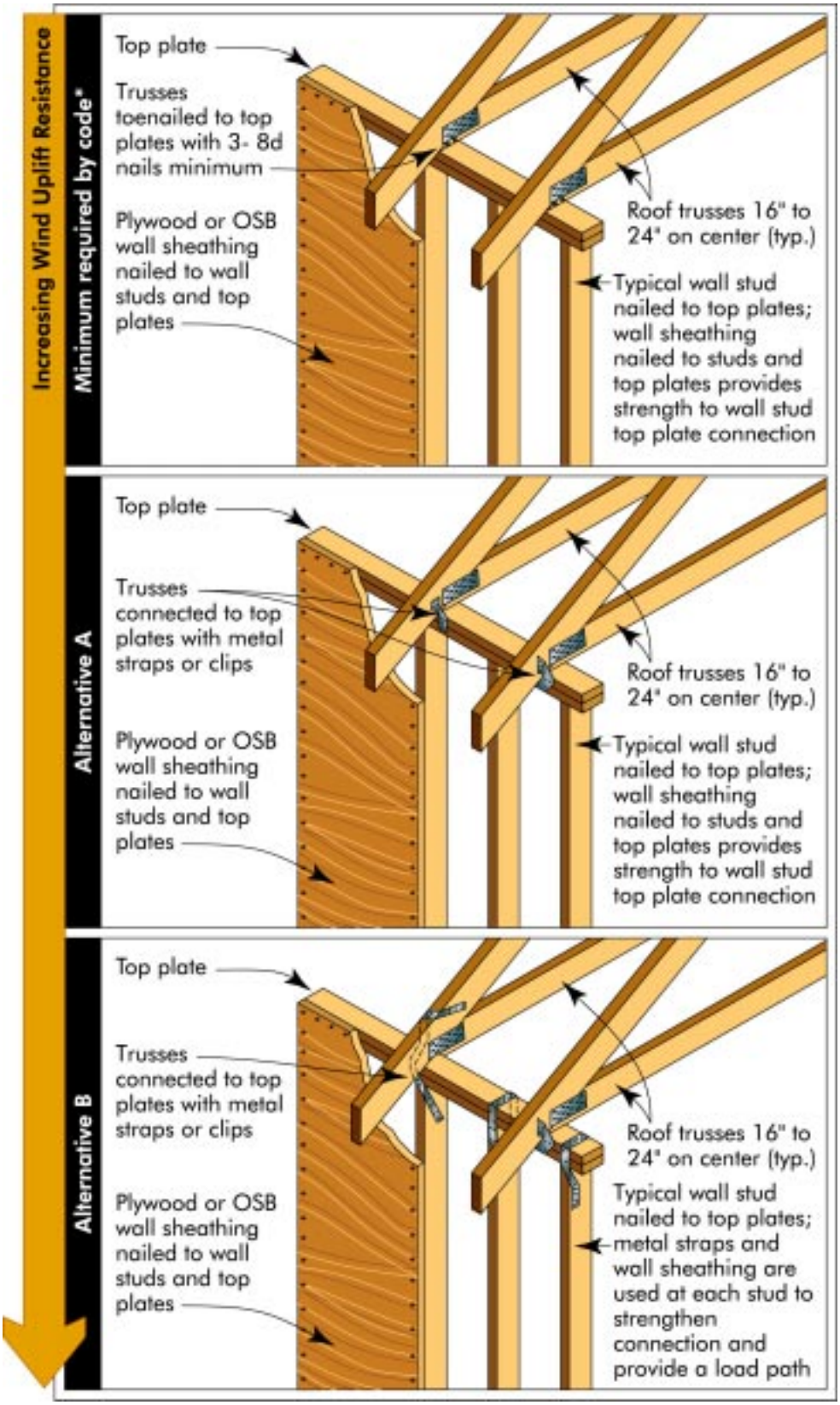


FIGURE 8-7: Roof truss to top-of-wall connection. The top detail illustrates the minimum connection that should be used in areas with basic wind speeds not exceeding 90-mph, 3 second peak gust (70-mph, fastest mile). Alternatives A and B illustrate connections that provide increasingly greater uplift resistance. * 1995 CABO One- and Two-Family Dwelling Code.

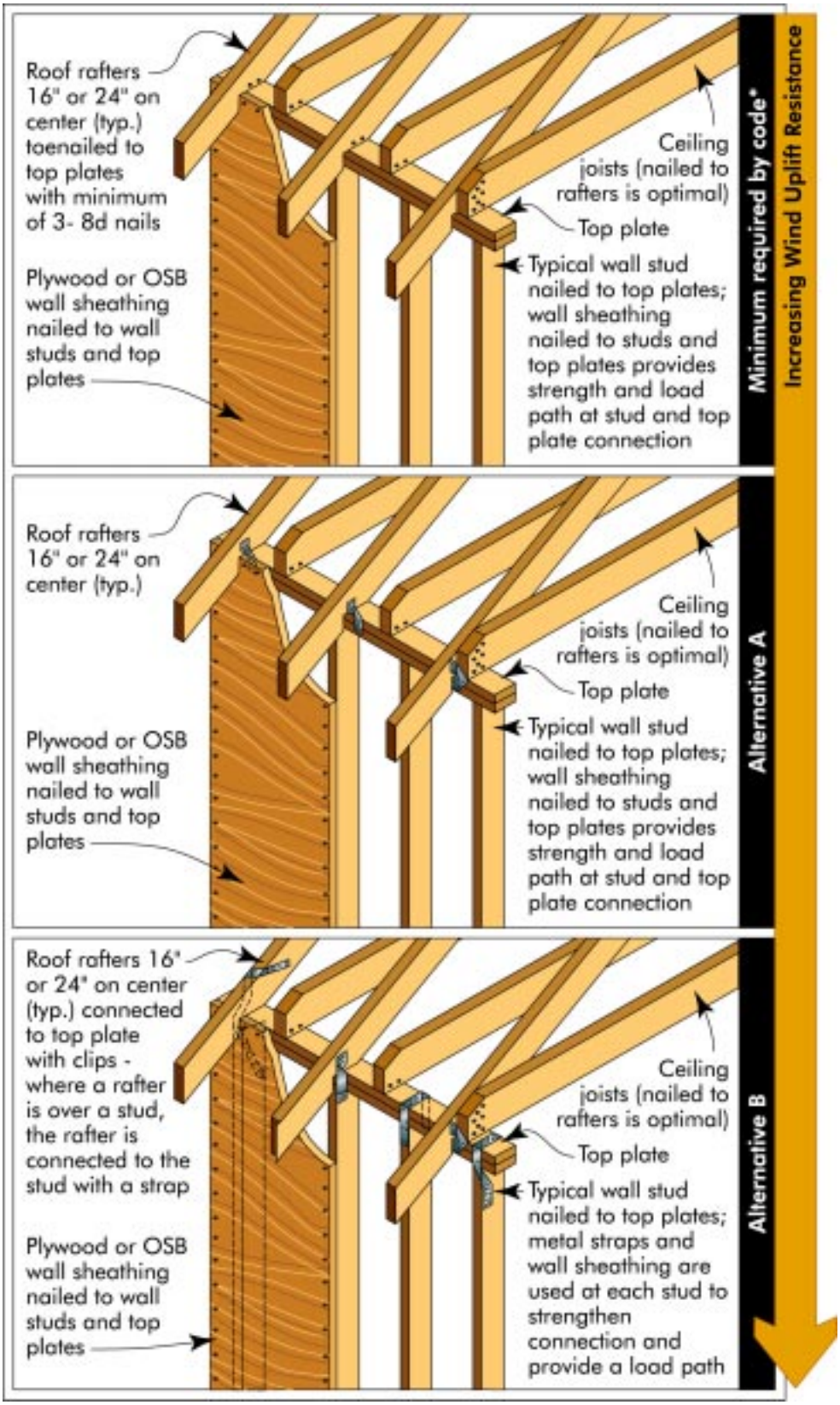


FIGURE 8-8: Roof rafter to top of wall connection. This connection is strongest when rafter is connected to ceiling joist as shown in this series of illustrations. The top detail illustrates the minimum connection that should be used in areas with basic wind speeds not exceeding 90-mph, 3 second peak gust (70-mph, fastest mile). Alternatives A and B illustrate connections that provide increasingly greater uplift resistance. * 1995 CABO One- and Two-Family Dwelling Code.

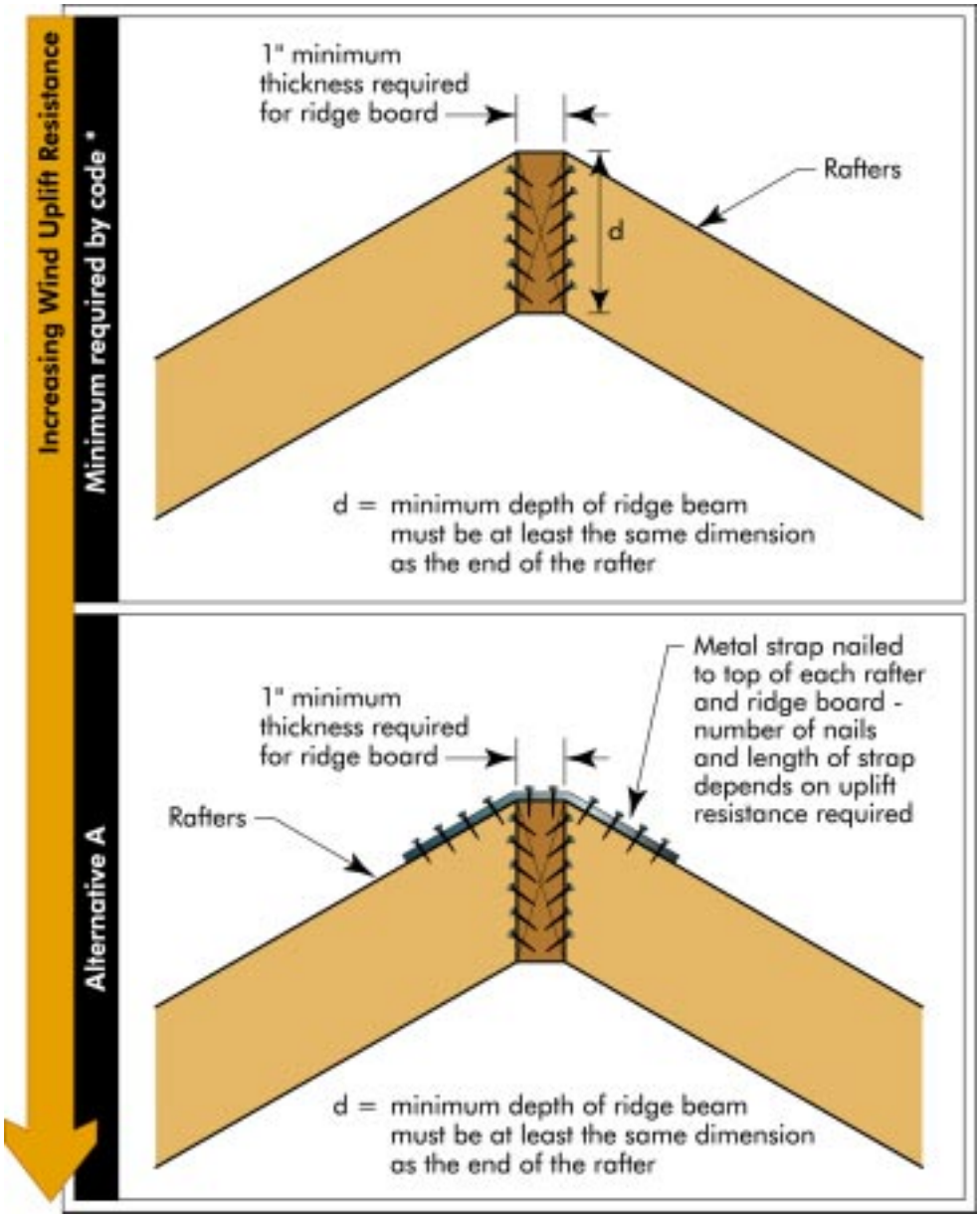


FIGURE 8-9: Roof rafters to ridge beam connection. The top detail illustrates the minimum connection that should be used in areas with basic wind speeds not exceeding 90-mph, 3 second peak gust (70-mph, fastest mile). Alternatives A and B illustrate connections that provide increasingly greater uplift resistance. * 1995 CABO One- and Two-Family Dwelling Code.

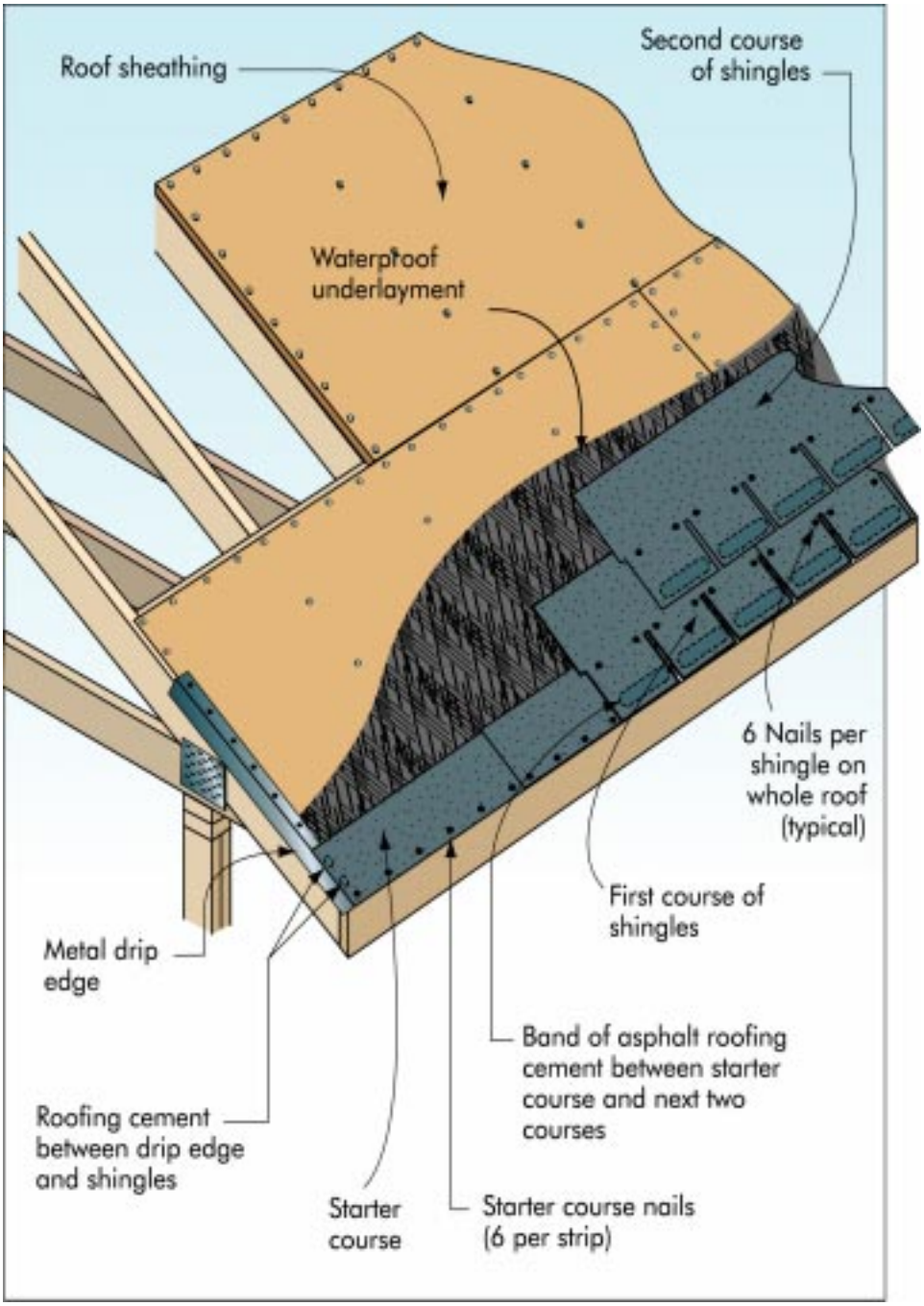


FIGURE 8-10: This illustration shows construction methods for asphalt roof shingle systems that provides improved resistance to uplift wind forces.

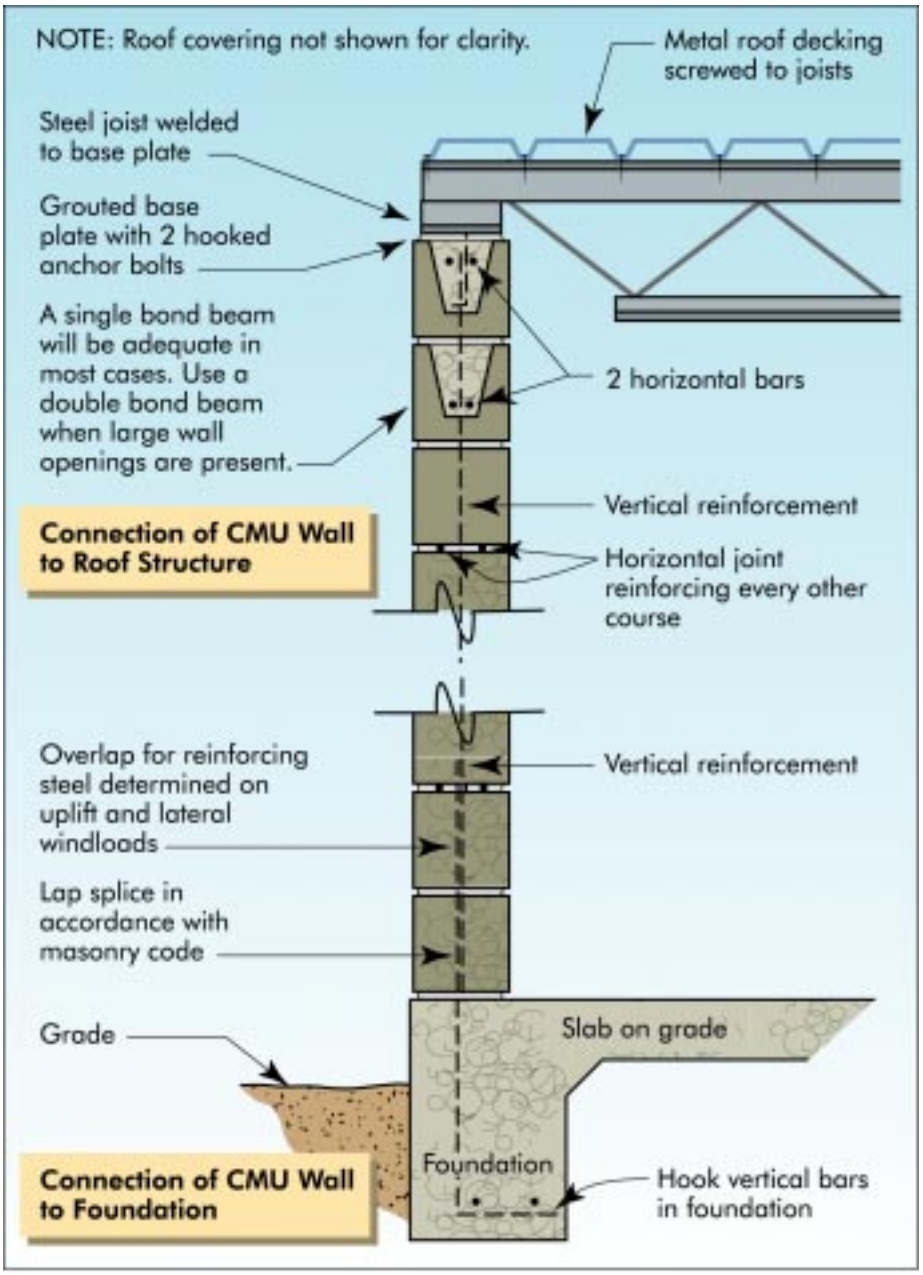
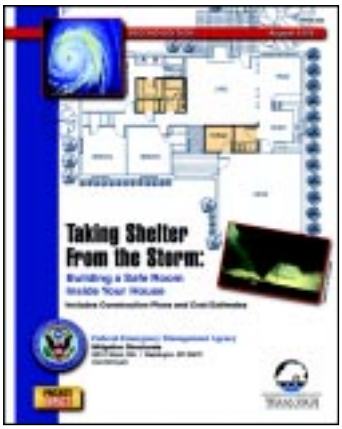


FIGURE 8-11: Proper connections in a reinforced masonry wall provide a continuous load path.

- Masonry walls that provide structural support to a building should be reinforced to resist gravity, lateral, and uplift loads.
- The model code organizations, in cooperation with the insurance industry and other interested parties should consider developing a wind speed map based upon probabilities, that demonstrates the increased risk associated with areas prone to high wind events such as tornadoes. This map could be based upon the research used to develop the wind speed risk

map in FEMA 320. Technical provisions provided with this new map could allow communities to identify their risk and decide if they would like to require higher design wind speeds.

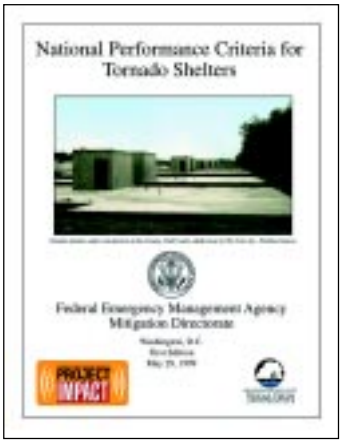
- Communities should consider the need for adopting ordinances and regulations that promote disaster-resistant communities by incorporating tornado shelters into new construction and communities.
- Fire departments and Emergency Services agencies should make a list of addresses with shelters, to assist in checking after a tornado to see if people are trapped inside.



See summary in Appendix C

8.3 Personal Protection

Shelters are the best means of providing near absolute protection for individuals who are attempting to take refuge during a tornado. Whether a shelter is constructed by a homeowner for protection of his or her family or is constructed as a group or community shelter, all shelters should be designed and constructed in accordance with either FEMA 320: *Taking Shelter from the Storm* (Appendix C) or *The National Performance Criteria For Tornado Shelters* (Appendix D). At a minimum, shelter doors should be constructed of 14 gauge hollow metal and be held by three hinges and three deadbolts. Ventilators should be constructed of heavy gauge steel or protected by heavy gauge shrouds or saddles to prevent their removal by the storm and the entrance of debris through the remaining openings. Below-grade portions of the shelter should be waterproof. All shelters should provide access to persons with disabilities as necessary and in conformance with the ADA. Local officials must monitor the installation of shelters to ensure that the floors of all shelters are located at or above expected flood levels and shelters in seismic areas must be designed and constructed to be seismic resistant in accordance with up-to-date building codes and engineering standards.



See Appendix D

8.3.1 Residential Sheltering

People should be encouraged to have in-residence or nearby shelters. Although this report advocates strengthening buildings to better resist high wind events, a shelter is still considered the only means of providing near absolute personal protection.

8.3.2 Group and Community Sheltering

The following recommendations are given regarding group and community shelters, and also address the reason people have congregated (i.e., residential, public areas, etc.):

FIGURE 8-12: Example of a tornado shelter provided in a place of business in Haysville, Kansas.

- Single-width manufactured homes on permanent foundations typically offer little protection from severe wind storms and tornadoes. In the event of such storms, occupants of manufactured homes should exit their homes and seek shelter in storm cellars, basements, or above-ground shelters. If shelters are provided in manufactured home parks, which is recommended, dispersed shelters, which can be accessed in a short time period, are recommended.
- Prospective occupants of community shelters should be acutely alert to storm warnings in order to allow sufficient time for the travel distance to the community shelter. Custodians of the shelter should be similarly alert so that the shelter is unlocked at appropriate times. Group and community shelters should be ADA compliant and the admission rules permanently posted (i.e. “No Pets Allowed,” etc.). A group shelter provided by an employer in Wichita, Kansas is shown in Figure 8-12.

- Essential facilities are critical to government response following a severe wind event or tornado. Site-specific evaluations should be made at essential facilities and other important facilities such as schools and daycare centers to determine the best locations for occupants during a storm. An assessment should be conducted to identify and provide signage to the designated refuge within or at the facility. The adequacy of the identified refuge to ensure people have a safe place to go and ample time to get there should be evaluated. Communities should consider enforcing this requirement by adopting an appropriate law or ordinance.
- Existing essential facilities that offer inadequate protection should have shelters retrofitted or a shelter added. New essential facilities should be designed with shelters. Interested states should form a committee to evaluate the need for tornado plans and shelters in essential facilities and other establishments serving the public (e.g., schools, hospitals, and critical facilities).
- All buildings in tornado-prone areas should have a tornado refuge plan of where to send people. In addition, all facilities for public accommodation should have a NOAA weather radio in continuous operation.

8.3.3 Places of Refuge

If a specifically designed tornado shelter is not available and refuge has to be taken in a residential or non-residential building, the following are recommended:

- State and local governments should develop education programs to assist homeowners and other property owners in developing a tornado safety plan similar to a fire safety plan. The plan should include the identification of a place of refuge and essential supplies. A tornado safety plan should include:
  - Seek refuge in a basement or below-grade crawl space, in an area away from the entry to the basement or crawl space. If the basement is partially above grade and has windows, seek shelter in a room within the basement that does not have windows.
  - If a residence does not have a basement or below-grade crawl space, seek refuge on the first floor in an interior bathroom or closet. If refuge is taken in a bathroom, lay in the tub.

- In a non-residential building that does not have a basement, seek refuge on the first floor in a concrete stair tower, interior corridor, or a small room that does not have glass openings in doors or walls and is as far inward as possible from exterior walls. Avoid rooms that have long roof spans more than 40 feet between walls or columns.
- Wherever refuge is taken, lay on the floor if space permits, or kneel down. Cover up with pillows or heavy blankets for added protection.