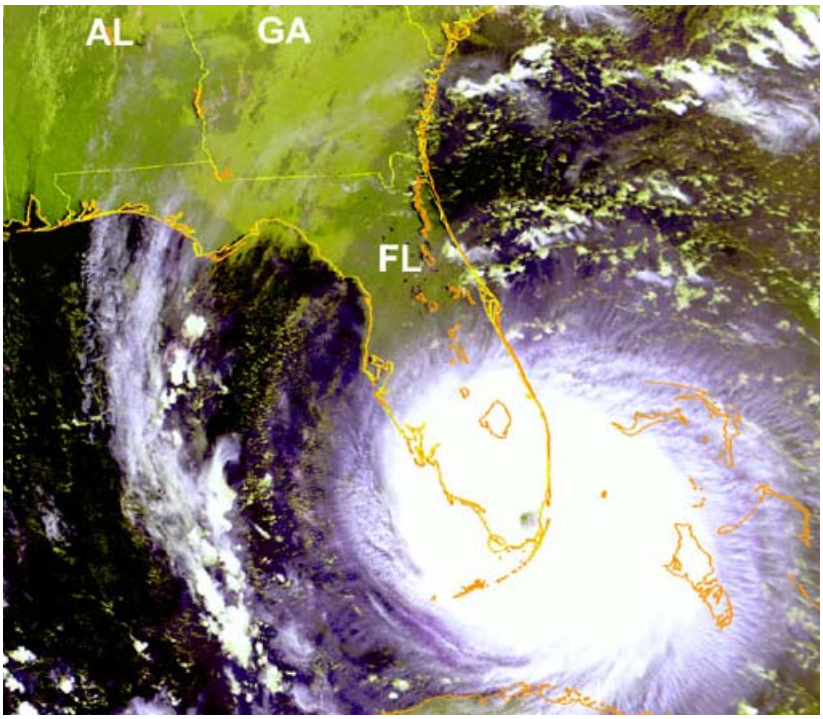
IN-HOME HURRICANE SHELTERING

PROTECT YOUR FAMILY



Building In-Home Retrofit Shelters for Existing Houses

Introduction

Tornadoes and hurricanes are some of the most destructive natural disaster causing phenomena. The state of Florida and other storm-prone areas have experienced a considerable impact from storm damage due to the hazardous effects of high winds and flooding from severe tropical storms and hurricanes. Table 1 and Table 2 list the categories and associated damage levels of hurricanes and tornadoes, respectively, provided by the National Hurricane Center (NHC). The tremendous increase in population growth in recent years has resulted in the increased need for residential construction, especially in coastal areas. Hurricanes such as Andrew and Opal have illustrated the susceptibility of Florida structures to the damaging storm effects. The growing concern for the state's vulnerability to storm-induced damage has made hurricane awareness and preparedness top priority for emergency management organizations. Planning and preparing for hurricanes involves such strategies as knowing risk areas, planning evacuation routes, preparing survival kits, protecting property and observing hurricane advisories. In addition, emergency management suggests installing in-house shelters with proper reinforcing

Who Needs a Shelter?

The state of Florida is located in a geographic area that experiences high storm activity. The vast shoreline extending several thousand miles increases the storm damage potential and vulnerability of residential structures along the coast. In recent years, residents have suffered tremendous property damage and even loss of life due to hurricane hazards. Most residential houses are constructed in accordance with

Table 1: Hurricane Categories and Typical Damage (NHC)

Category	Wind Velocity Range	Typical Damage
C1	74-95 mph	**Minimal**: No real damage to buildings. Some damage to unanchored mobile homes and poorly constructed signs.
C2	96-110 mph	**Moderate**: Some damage to building roofs, doors and windows. Some toppled trees. Major damage to mobile homes.
C3	111-130 mph	**Extensive**: Some structural damage to small homes and utility buildings. Large trees are toppled. Mobile homes are destroyed.
C4	131-155 mph	**Extreme**: Extensive damage to roofs, windows and doors. Complete roof structure failure on small homes. Some curtain wall failure
C5	156 mph and up	**Catastrophic**: Complete roof failure on many homes and industrial buildings. Some complete buildings fail. Evacuation may be required

Table 2: Tornado Categories and Typical Damage (NHC)

Category	Wind Velocity Range	Typical Damage
F0	40-72 mph	**Minimal**: Some damage to chimneys. Tree branches broken off. Shallow rooted trees uprooted.
F1	73-112 mph	**Moderate**: Peels surface off roofs. Mobile homes overturned. Moving autos pushed off roads.
F2	113-157 mph	**Significant**: Considerable damage. Roofs torn off frame houses. Large trees snapped or uprooted. Light-object missiles generated.
F3	158-206 mph	**Extreme**: Severe damage. Roofs and some walls torn off well-constructed homes. Trains overturned. Most trees in forests uprooted. Heavy cars lifted off ground.
F4	207-260 mph	**Catastrophic**: Well-constructed houses leveled. Structures with weak foundations blown off some distance. Cars thrown and large missiles generated.
F5	261-318 mph	**Incredible:** Strong framed houses lifted off foundations and disintegrated Automobile-sized missiles fly through the air in excess of 100 mph. Trees debarked.

local building codes that may not take into account the effects of extreme winds associated with hurricanes. For this reason it is imperative to take the necessary precautions to secure your home and family from harm.

The objective of this manual is to provide design and construction guidelines for a Retrofit Room, which is an in-residence shelter alternative geared towards existing houses. Such a room will be able to withstand wind speeds up to 140 mph. Certainly, it will be more preferable to have in-house protection than none at all. The in-house shelter will offer significant occupant protection and reduce the demand on public shelters during the events of hurricanes and tropical storms. The design criteria and construction specifications for the retrofit room developed are based on the known performance and strengths of existing materials and technology. Retrofit techniques make use of external reinforcement for wall and roof sections of existing interior rooms to provide a convenient and readily accessible shelter for residents. Its basis comes from post-storm observations that show the tendency of interior rooms to remain intact even when the rest of the house is damaged or destroyed.

Retrofit Room Design

The design of the Retrofit Room is specifically geared towards "typical" existing houses in the state of Florida. Single-family residential houses with wood-framed or concrete masonry structures on slab-on-grade foundations were chosen as model buildings for the design. Shelter size and location of the retrofitted room depend on the layout of the house. Feasibility and cost efficiency were the key factors in developing the Retrofit Room technique for existing houses. Strengthening structural components with external sheathing, extra members, additional anchorage and better connections were

some of the retrofit strategies selected to reinforce interior rooms. The materials most capable of resisting the effects of debris impact, overturning and uplift were utilized to provide adequate protection during the event of a storm. The primary criteria for performance required that the entire room envelope stay intact throughout exposure to extreme wind and debris impact.

One of the leading causes in building failure during high-wind events is the failure of connections between building elements. It is mandatory to provide adequate roof-to-wall and wall-to-foundation connections to ensure a continuous load path to maintain the integrity of the structural system. Hurricane straps, anchor bolts and nails are some of the connections used to secure the Retrofit Room and provide resistance to uplift, overturning, and sliding caused by extreme winds.

The Retrofit Room design is based on wind speeds reaching 140 mph, which accounts for the majority of hurricanes making landfall in the United States. Such extreme winds have the potential to generate windborne debris with forces to penetrate walls and roof systems. Because of the danger associated with flying debris, structures located in hurricane-prone areas (regions with 120+ mph basic wind speeds) are required to undergo debris impact testing. Florida Building Code debris testing specifications for materials require that structural components resist penetration of a standard 2 by 4 in. wood stud weighing 9 lbs striking on end at a speed of 34 mph. The Retrofit Room design utilizes material combinations that will withstand missile impact.

Modifications to Existing Frame

In smaller houses that may not have exclusively interior rooms, it is necessary to use at most two exterior walls in the design of the shelter. The exterior walls will

maintain their function as structural load bearing walls; however, measures have been taken to allow the walls to detach during the event of a hurricane. For the stud wall, a notch will be cut into the studs just above the ceiling of the retrofit room reducing the width and causing the upper part of the wall to break away when additional loads from wind pressures are applied. The imposed notch results in a stud area reduction of 22.5 percent (4.07 in^2 from 5.25 in^2). For the concrete masonry wall, construction joints will be used to allow for lateral movement to prevent damage to the assembly and maintain structural integrity. Cutting through the masonry with a saw, and inserting a foam rod to create a functional joint can achieve post-construction installation of joints.

Materials and Cost

Materials for the design were chosen based on their performance strength and durability to withstand excessive wind forces and impact. Selected items include plywood, wood stud members, steel sheathing, hurricane straps, Dade County certified door, anchor bolts and nails. To ensure practicality and accessibility for homeowners, materials readily available at local hardware stores are needed. Included in this manual is a detailed list of materials used in building a Retrofit Room.

Various factors including shelter size, materials and labor, and geographical location have an effect on the overall cost. The cost analysis of retrofitting a typical interior room for existing houses was based on the selected materials used for the construction of a standard size 6 by 6 by 8-ft. demonstration Retrofit Room. The average cost of retrofitting an interior room is about $3,000 depending on the shelter type and size.

Retrofit Room Construction

Included in this manual are plans of the typical retrofit room designs developed through research. In addition, photographs from the construction of an actual freestanding demonstration Retrofit Room located at the FAMU-FSU College of Engineering in Tallahassee, FL are provided to show the various stages of construction sequence.

DESIGN SPECIFICATIONS

1. WOOD:

   A. FRAMING LUMBER TO HAVE MODULUS OF ELASTICITY = 1,200,000 PSI MIN. AND F_b = 1250 PSI MIN.
   EXAMPLES OF ACCEPTABLE GRADE AND SPECIES OF FRAMING LUMBER INCLUDE #2 AND BETTER SPRUCE-PINE-FIR AND SOUTHERN YELLOW PINE.

   B. PLYWOOD TO BE RATED SHEATHING SPAN RATING 40/20, MIN. 3/4 THICKNESS.

   C. NAILS TO BE COMMON WIRE NAILS.

   D. ANCHOR BOLTS TO BE STANDARD ASTM A307 ½" DIAMETER BOLTS WITH MINIMUM YIELD STRENGTH OF 45 KSI.

   E. HURRICANE STRAPS TO BE SIMPSON STRONG-TIE H15 CONNECTORS TO RESIST MAXIMUM UPLIFT OF 1300 LBS.

2. MASONRY:

   A. MASONRY UNITS SHALL HAVE ULTIMATE COMPRESSIVE STRENGTH (f'_m) OF 1500 PSI AT 28 DAYS.
   B. MORTAR TO BE TYPE M OR S PER ASTM C270-97.

C. REINFORCING SHALL BE MILD STEEL WITH A MINIMUM YIELD STRENGTH OF 60 KSI.

3. STEEL SHEATHING:

   A. YIELD STRENGTH FOR METAL IS 36 KSI MINIMUM
   B. ALL METAL SHALL BE G60 GALVANIZED BY THE MANUFACTURER.

4. RETROFIT DOOR TO BE MIAMI-DADE COUNTY CERTIFIED FOR WIND AND LARGE MISSILE DEBRIS IMPACT.

5. LIVE LOADS USED IN DESIGN:

   A. WIND PRESSURES DEVELOPED FROM 140 MPH 3-SEC. PEAK GUST IN ACCORDANCE WITH ASCE 7-98
   B. WINDBORNE DEBRIS (MISSILE) IMPACT LOADS CREATED BY A 9-LB 2X4 TRAVELING HORIZONTALLY AT 34 MPH AND IMPACTING NORMAL TO WALL SURFACE

RETROFIT PROCEDURE

Step 1 Locate a suitable windowless interior room, preferably a closet, bathroom or utility room. Obtain and record actual dimensions of existing wall and roof length, width and height.

Step 2 Select an appropriate retrofit choice from Alternatives 1, 2 and 3. Obtain the materials needed from a local hardware store.

Step 3 Remove existing door and external or internal wall covering (i.e. sheetrock, drywall) from interior room wall and roof.

Step 4 Check existing anchor bolt spacing and connection detail. If necessary, install additional anchors, or modify existing anchors with proper size and embedment.

Step 5 Determine new wall height (maximum of 8 feet) to ensure that Retrofit Room ceiling is not attached to existing ceiling. For wood frame rooms having up to two exterior walls, a notch must be cut into the studs just above the retrofit ceiling to allow the house to "break away" from the shelter. For exterior CMU walls, saw cut the masonry to install construction joints to prevent progressive damage from lateral movement.

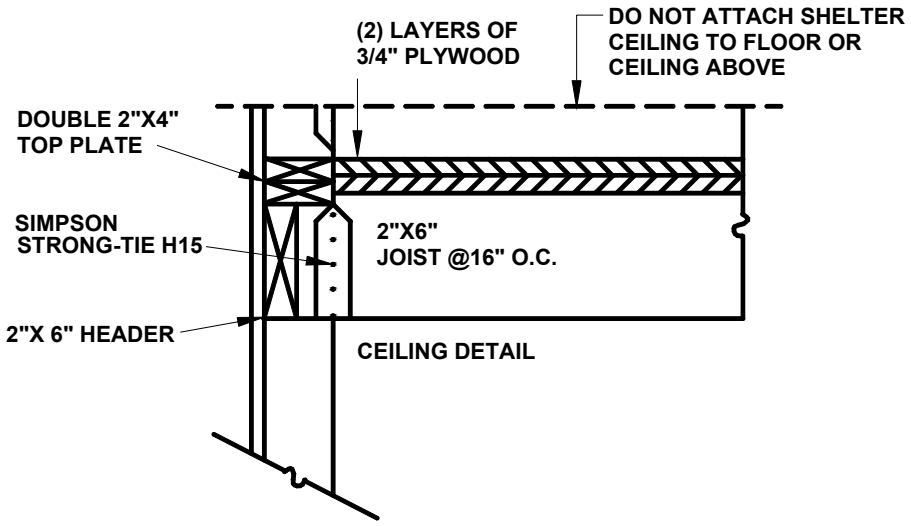
Step 6 Assemble retrofit ceiling using 2" x 6" joists spaced at 16 in. on center and attach to stud wall. If necessary, allow for installation of exhaust fan for ventilation purposes.

Step 7 Install Simpson Strong-Tie H15 hurricane straps at each end of ceiling joists and fasten to studs with 12-10d nails.

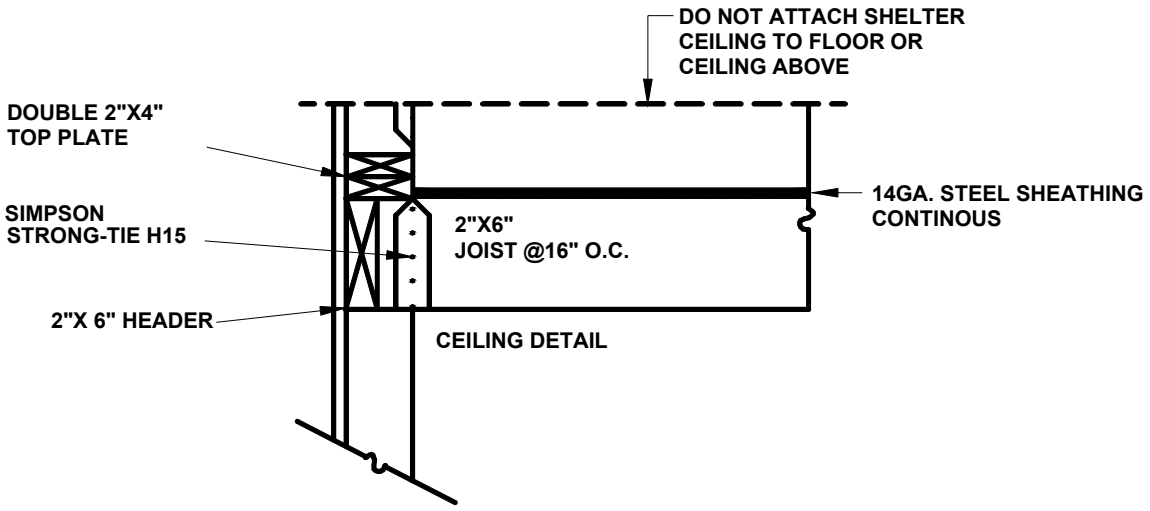
Step 8 Attach reinforcement (i.e. plywood or steel sheathing) to retrofit ceiling and walls in accordance with the attachment schedule.

Step 9 Re-install interior or exterior finish (gypsum drywall) to wall and ceiling.

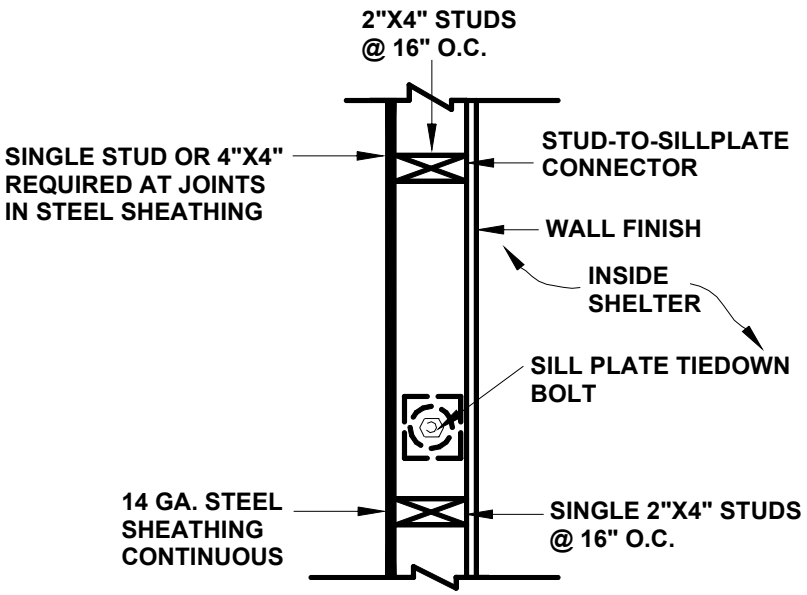
Step 10 Install special Dade County approved retrofit door.



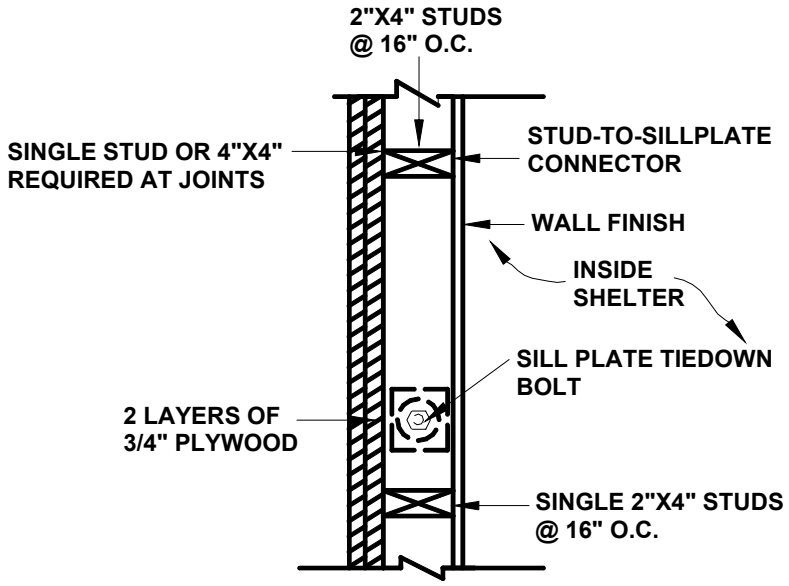
Retrofit Choice 1 Ceiling Detail



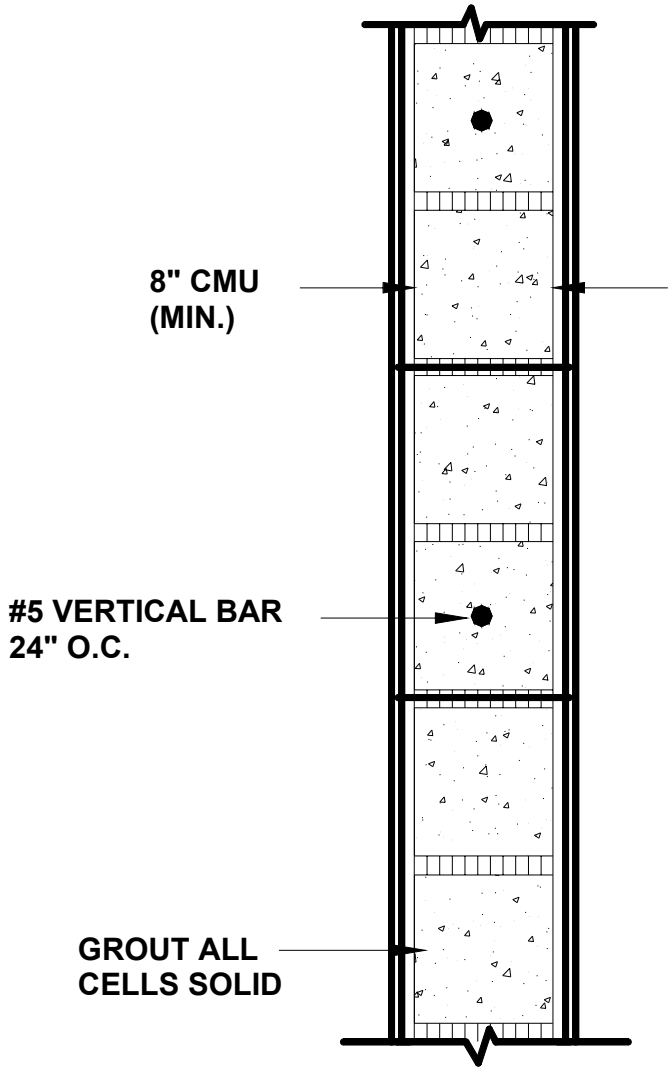
Retrofit Choice 2 Ceiling Detail



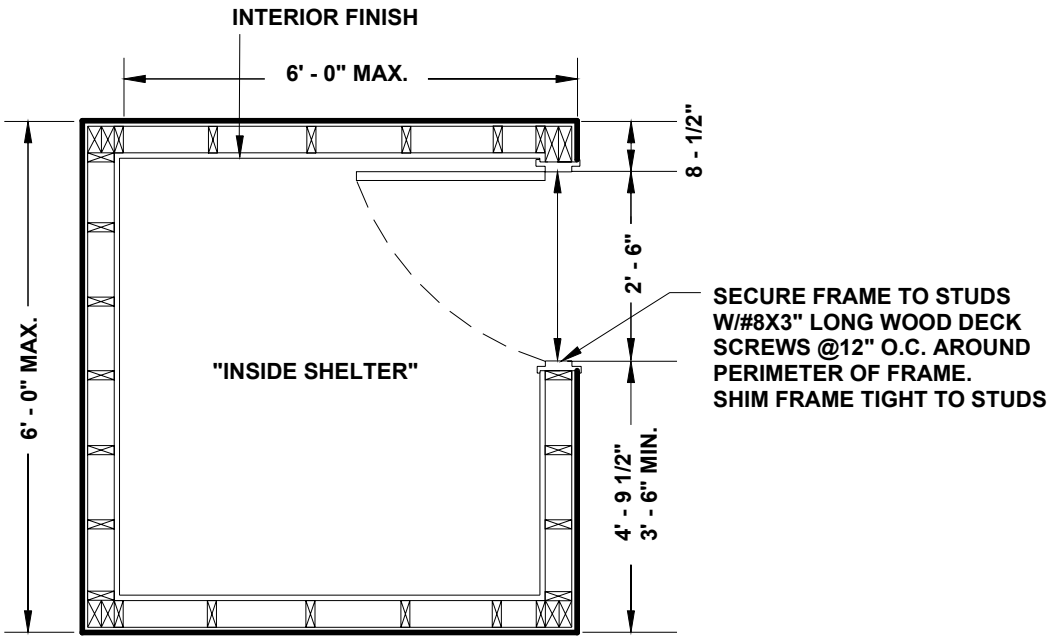
Alternative 1 Wall Detail (Wood Frame Home)



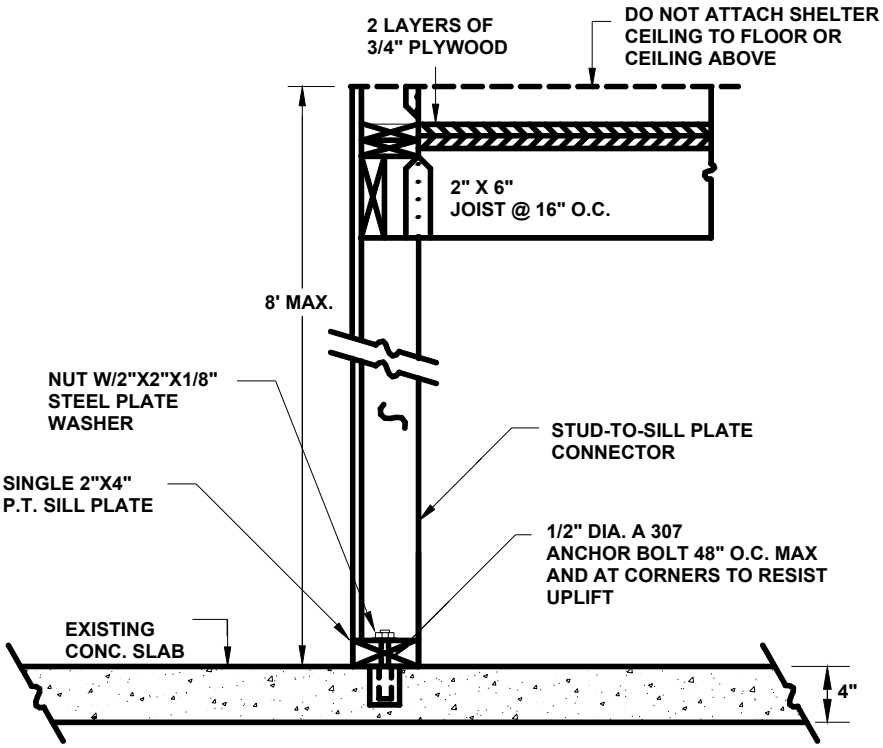
Alternative 2 Wall Detail (Wood Frame Home)



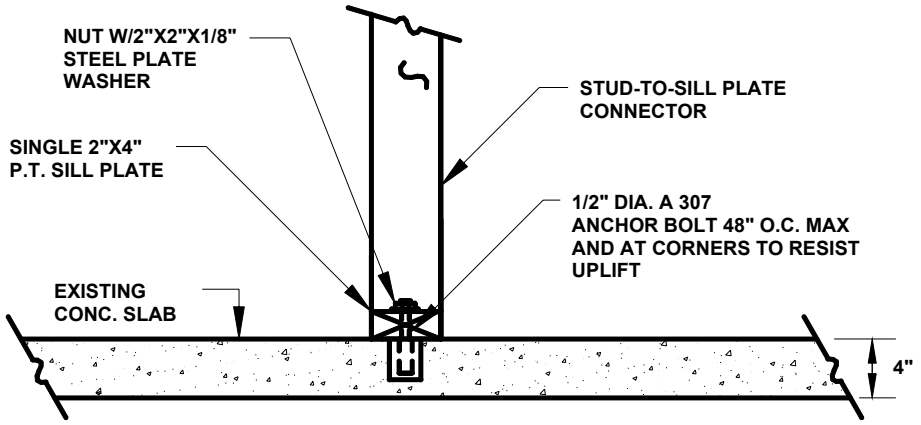
Alternative 3 Wall Detail (Block Masonry Home)



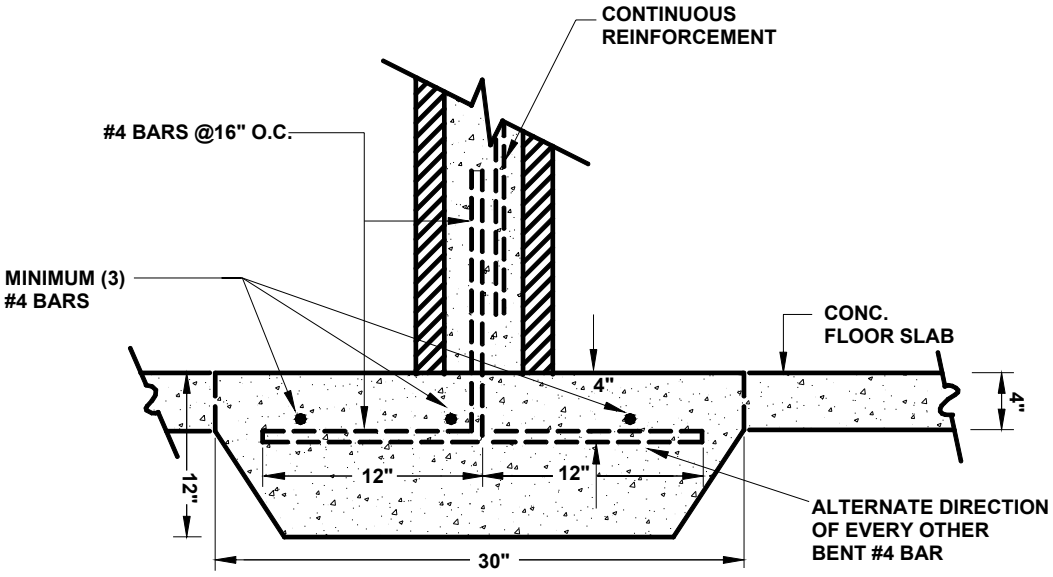
Typical Plan View



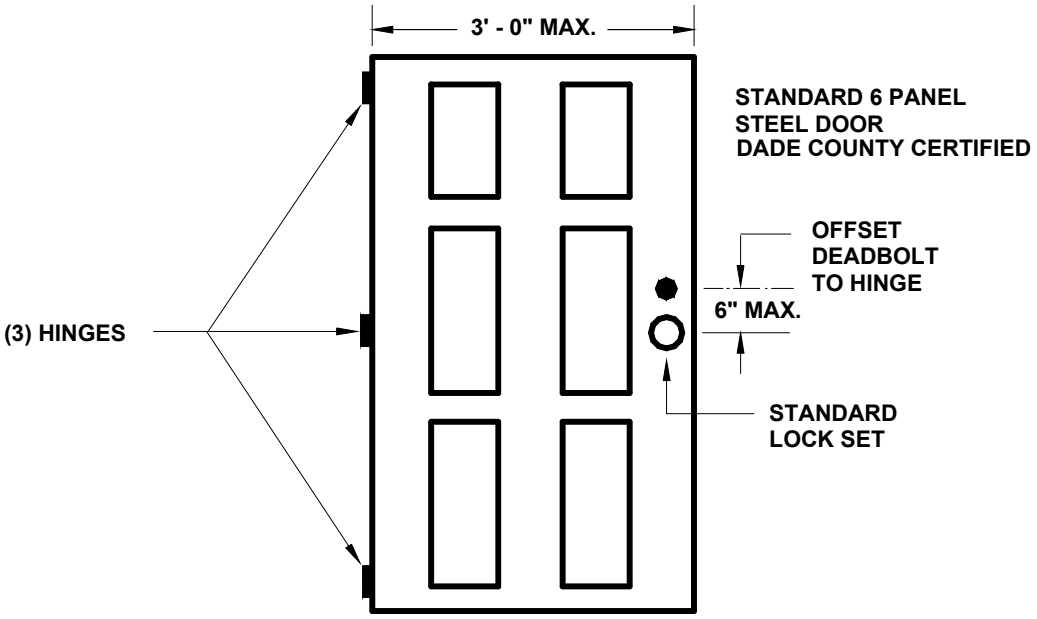
Typical Wall Elevation



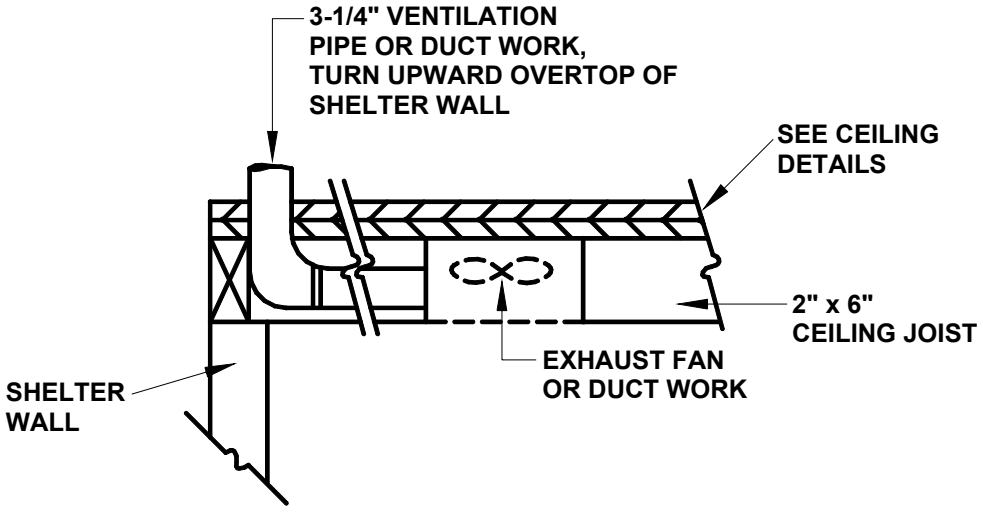
Typical Anchor Detail for Wood Walls on Slab-on Grade Foundation



Typical Anchor Detail for CMU Wall on Slab-on-Grade Foundation



Retrofit Door Detail



Ceiling Exhaust Fan Detail

Attachment Schedule

Sheathing Material	10d Nails	16d Nails	¼" x 2" Self-Tapping Screws
First layer of plywood	3" o.c. @ edges 6" o.c. in field		
Second layer of plywood		3" o.c. @ edges 6" o.c. in field	
Steel Sheathing			3" o.c. @ edges 6" o.c. in field

Alternate Attachment Schedule

Sheathing Material	#6x1-1/2" Wood Deck Screws	#8x3" Wood Deck Screws	#6x1" Wood Deck Screws
First layer of plywood	3" o.c. @ edges 6" o.c. in field		
Second layer plywood		3" o.c. @ edges 6" o.c. in field	
Steel Sheathing			3" o.c. @ edges 6" o.c. in field

Materials List for Alternative 1

Walls			
Material	**Size**	**Measure**	**Quantity**
Lumber	2” x 6” x 8’	Each	1
Gypsum (Dry Wall)	1/2”	4’ x 8’ Sheet	8
Dry wall Tape	250’ Roll	Each	1
Steel Sheathing	14 Gauge	4’x 8’ Sheet	8
Joint Compound	4 1/2 Gallon	Each	1
Dry Wall Sand Paper	4" x 8"	Package	1
Taping Knife	12"	Each	1
Ceiling			
Material	**Size**	**Measure**	**Quantity**
Lumber	2" x 6" x 8'	Each	8
Steel Sheathing	14 Gauge	4’ x 8’ Sheet	2
Gypsum (Dry Wall)	1/2"	4' x 8' Sheet	2
Hardware			
Material	**Size**	**Measure**	**Quantity**
Prehung Door/	30” Solid	Each	1
Anchor Bolts	5 1/2”	Box of 10	1
Plate Washer	2”x2”x1/8”	Each	10
Joist-Stud Ties	H15	Each	12
Stud-Plate	H6	Each	12
16d Nails		30 Lbs	1
10d Nails		5 Lbs	1
Drywall Screws	1 5/8”	5 Lbs	2
Dead Bolts	1” min	Each	1
Self Tapping Screws	¼” x 2”	Box of 250	4
Standard Door Handle		Each	1
Misc.			
Material	**Remarks**	**Measure**	**Quantity**
2 part Epoxy	Caulk Tube	Each	1

Materials List for Alternative 2

Walls			
Material	**Size**	**Measure**	**Quantity**
Plywood	3/4"	4' x 8' Sheet	16
Lumber	2” x 6” x 8’	Each	1
Gypsum (Dry Wall)	1/2”	4’ x 8’ Sheet	8
Dry wall Tape	250’ Roll	Each	1
Joint Compound	4 1/2 Gallon	Each	1
Dry Wall Sand Paper	4" x 8"	Package	1
Taping Knife	12"	Each	1
Ceiling			
Material	**Size**	**Measure**	**Quantity**
Lumber	2" x 6" x 8'	Each	8
Plywood	3/4"	4' x 8' Sheet	4
Gypsum (Dry Wall)	1/2"	4' x 8' Sheet	2
Hardware			
Material	**Size**	**Measure**	**Quantity**
Prehung Door/	30” Solid	Each	1
Anchor Bolts	5 1/2”	Box of 10	1
Plate Washer	2”x2”x1/8”	Each	10
Joist-Stud Ties	H15	Each	12
Stud-Plate	H6	Each	12
16d Nails		30 Lbs	1
10d Nails		5 Lbs	1
Drywall Screws	1 5/8”	5 Lbs	2
Dead Bolts	1” min	Each	1
Standard Door Handle		Each	1
Misc.			
Material	**Remarks**	**Measure**	**Quantity**
2 part Epoxy	Caulk Tube	Each	1

Materials List for Alternative 3

Walls			
Material	**Size**	**Measure**	**Quantity**
Lumber	2” x 6” x 8’	Each	1
Plywood	3/4”	4’ x 8’ Sheet	8
Gypsum (Dry Wall)	1/2”	4’ x 8’ Sheet	8
Dry wall Tape	250’ Roll	Each	1
Joint Compound	4 1/2 Gallon	Each	1
Dry Wall Sand Paper	4" x 8"	Package	1
Taping Knife	12"	Each	1
Ceiling			
Material	**Size**	**Measure**	**Quantity**
Lumber	2” x 6” x 8’	Each	8
Plywood	3/4”	4’ x 8’ Sheet	4
Gypsum (Dry Wall)	1/2”	4’ x 8’ Sheet	2
Hardware			
Material	**Size**	**Measure**	**Quantity**
Prehung Door/	30” Solid	Each	1
Anchor Bolts	5 1/2”	Box of 10	1
Plate Washer	2”x2”x1/8”	Each	10
Joist-Stud Ties	H15	Each	12
Stud-Plate	H6	Each	12
16d Nails		30 Lbs	1
10d Nails		5 Lbs	1
Mortar	80 lb bag	Bag	10
Drywall Screws	1 5/8”	5 Lbs	2
Dead Bolts	1” min	Each	1
Rebar	#5 (5/8”)	10’ Each	12
Standard Door Handle		Each	1
Misc.			
Material	**Remarks**	**Measure**	**Quantity**
2 part Epoxy	Caulk Tube	Each	1

Stud Wall Construction

Stud Wall with Roof Joists

Bottom Plate Strap and Anchor Connection

Anchor and Strap Detail

Corner Detail

Plywood Attachment Spacing Detail

Plywood Sheathing Attachment

Roof-to-Wall Connection Detail

Exterior Sheathing

Gabled Roof Connection