4 NONSTRUCTURAL EXAMPLES: EARTHQUAKE DAMAGE AND UPGRADE DETAILS

This chapter includes specific examples of selected nonstructural items. In most cases, the example includes a photograph of earthquake damage that occurred to an unanchored or inadequately anchored item paired with a drawing of suggested upgrade details that can be used to reduce the seismic vulnerability of the item. Some of these are simple, generic details that can be installed by a handyman; these details are marked *Do-It-Yourself.* Others are schematic details that need to be developed by a design professional for a particular situation and in some instances will require installation by a specialty contractor; these details are marked *Engineering Required.* Enough examples have been provided to allow for an effective initial survey of most ordinary-occupancy buildings. The end of this chapter includes installation guidelines to accompany the *Do-It-Yourself* details.

NONSTRUCTURAL EXAMPLES

Photos of earthquake damage and suggested upgrade details are presented for a variety of common nonstructural items. While these examples do not cover every case, many items not included here would be damaged and/or upgraded in a manner similar to one that is shown. For example, the detail shown for an air compressor is applicable to many pieces of mechanical or HVAC equipment that are mounted on vibration isolation springs. Similarly, the wall and floor anchorage details shown for tall shelving or file cabinets are applicable to other items, such as storage cabinets or personnel lockers. The detail shown for a fire extinguisher could also be applied to a fire hose cabinet. Many types of desktop or countertop equipment found in offices, hospitals, or laboratories could be restrained by using the suggestions for desktop computers, although special detailing may be warranted for expensive equipment. Seismic protection schemes for newly installed items are often similar to the anchorage or restraint details shown.

The examples have been divided into three categories: utility systems that are part of the building; built-in architectural components; and furniture and contents, which are typically the property of the occupants or tenants rather than a permanent part of the building. The examples are listed in Figure 8.

Earthquake Damage The photographs presented here cover a variety of situations and have been taken over a 25-year period. Photographs from the 1971 San Fernando earthquake generally show damage to items that were not restrained, while some of the more recent photographs depict damage to items that appeared to be braced or anchored but whose bracing and anchoring details were apparently inadequate to resist the severity of the shaking.

Upgrade Details The examples presented in this chapter show representative details for protecting common items from earthquake damage. The two different types of details are described below.

- ***Do-It-Yourself*** These are simple, generic details for typical nonstructural items. Enough information is provided that a handyman can install them using common tools and readily

available materials. Most of the examples for furniture and contents include simple details that are marked *Do-It-Yourself.* These details are applicable for many common items found in the home, office, or small business. At the end of this chapter are guidelines on the proper use and installation of these details.

• ***Engineering Required*** These are schematic details showing common solutions for the items in question. These sketches do not contain sufficient information for installation; they are provided primarily as an illustration of the required scope of work. The designation *Engineering Required* has been used for items where the self-help approach is most likely to be ineffective. The recommendation of this guide is that design professionals be retained to evaluate the vulnerability of these items and design appropriate anchorage or restraint details, particularly where safety is an issue. As stated earlier, this recommendation may apply to all items in specialized facilities such as hospitals and emergency operations or communications centers, where interruption or loss of function is unacceptable.

Recent experience has shown many instances where fire sprinkler and other water lines, HVAC equipment, emergency generators, water tanks, ceilings, parapets, glazing, and so on were damaged when subjected to severe shaking and failed to perform as expected. The lesson learned from this experience is that the protection of many items, particularly building utilities and architectural components in facilities that are expected to remain functional during and after a major earthquake, is a complex undertaking that should be addressed by engineers and architects with specific expertise in this area. As a result, most building utility systems and architectural components have been given the designation *Engineering Required.* Several of the items listed under furniture and contents have also been given this designation.

The upgrade details for these items are schematic only and are presented here with estimated installation costs, primarily for planning and/or budgeting purposes. Facilities personnel can use this information in conjunction with the survey forms and checklists included in this guide to estimate the scope of the work needed and obtain initial cost estimates for planning purposes.

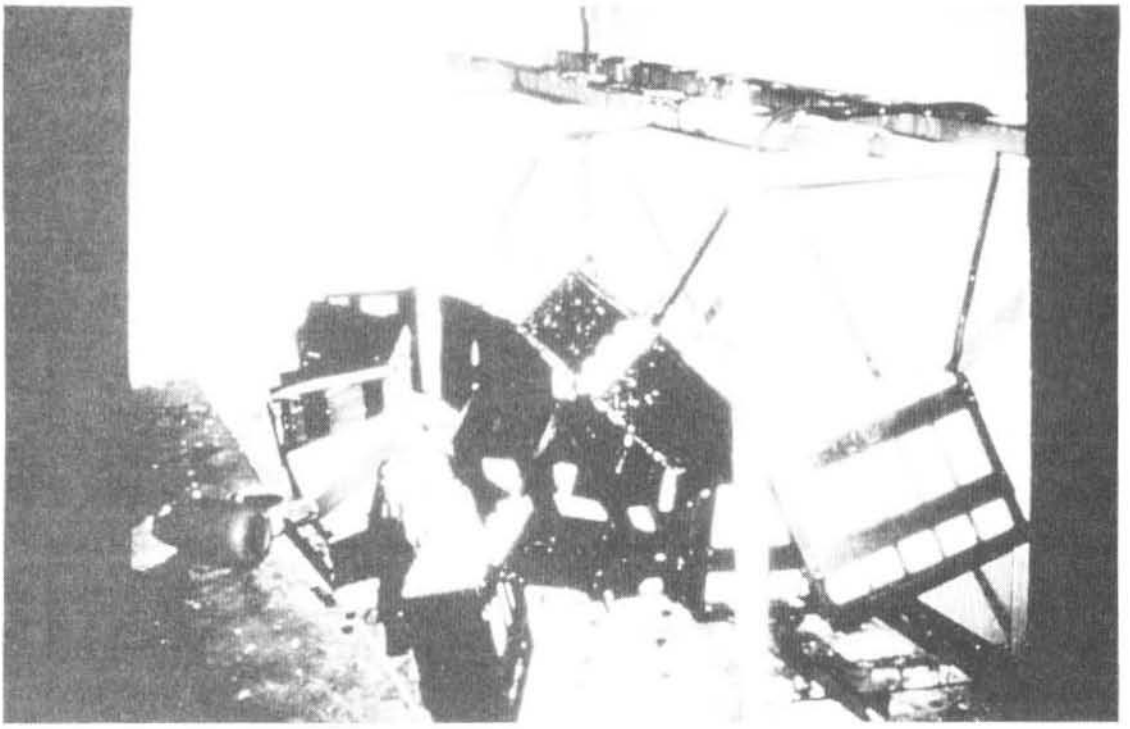
Upgrade Cost The cost estimates provided with the details in this chapter may be used as a rough guide for planning or budgeting purposes. The values are intended to cover the costs of materials and labor. They do not include any allowance for architectural or engineering fees, permits, special inspection, etc. These estimated costs represent a professional opinion based on information available at the time of publication in 1994. Actual construction costs may vary significantly, depending on the timing of construction, changes in conditions, the availability of materials, regional cost variations, and other factors.

Figure 8 : Nonstructural Examples

Detail	Nonstructural Item	Type of Detail	Page
U	**BUILDING UTILITY SYSTEMS**		
U2	Batteries and Battery Rack	Engineering Required	30
U3	Diesel Fuel Tank	Engineering Required	31
U8	Electrical Bus Ducts and Primary Cable System	Engineering Required	32
U10	Fire Extinguisher and Cabinet	Do-It-Yourself	33
U15	Propane Tank	Engineering Required	34
U19a	Water Heater: Corner Installation	Do-It-Yourself	35
U19b	Water Heater: Wall Installation	Do-It-Yourself	36
U21	Piping	Engineering Required	37
U29	Chiller	Engineering Required	38
U32	Air Compressor (or other HVAC Equipment)	Engineering Required	40
U35	Suspended Space Heater	Engineering Required	41
U36	HVAC Distribution Ducts	Engineering Required	42
U37	Air Diffuser	Do-It-Yourself	43
U38	Residential Chimney	Engineering Required	44
A	**ARCHITECTURAL ELEMENTS**		
A2a	Built-In Partial-Height Partitions	Engineering Required	45
A2b	Built-In Full-Height Partitions	Engineering Required	46
A3	Suspended T-Bar Ceilings	Engineering Required	47
A5a	Suspended Light Fixtures	Do-It-Yourself	48
A5b	Pendant Light Fixtures	Do-It-Yourself	49
A9	Stairways	Engineering Required	50
A12	Windows	Engineering Required	51
A15a	Unreinforced Brick Parapets	Engineering Required	52
A15b	Veneer	Engineering Required	53
A16	Freestanding Walls or Fences	Engineering Required	54
A21	Exterior Signs	Engineering Required	55

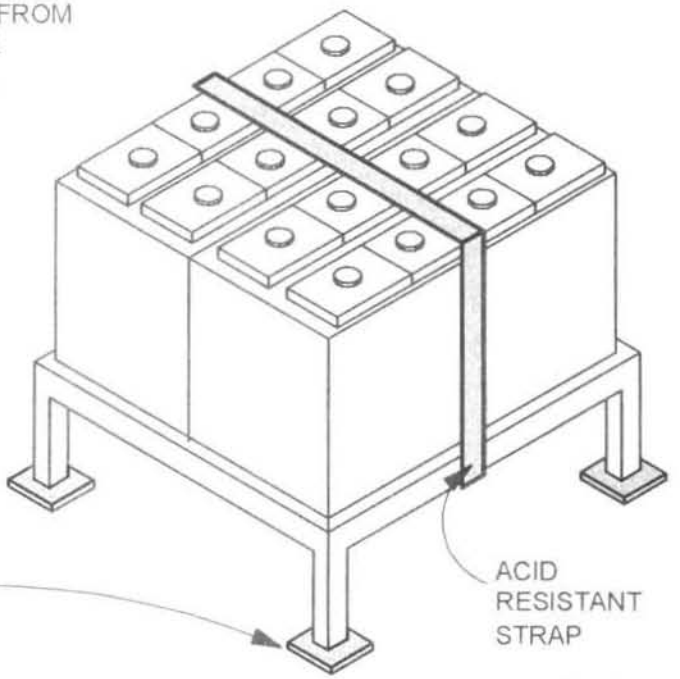
BATTERIES AND BATTERY RACK

ENGINEERING REQUIRED



Earthquake Damage: 1971, San Fernando, California
Photo Credit: John F. Meehan

SEISMIC RESISTANT BATTERY RACKS ARE AVAILABLE FROM VENDORS THAT MAY BE BOLTED TO THE FLOOR AND/OR WALL.



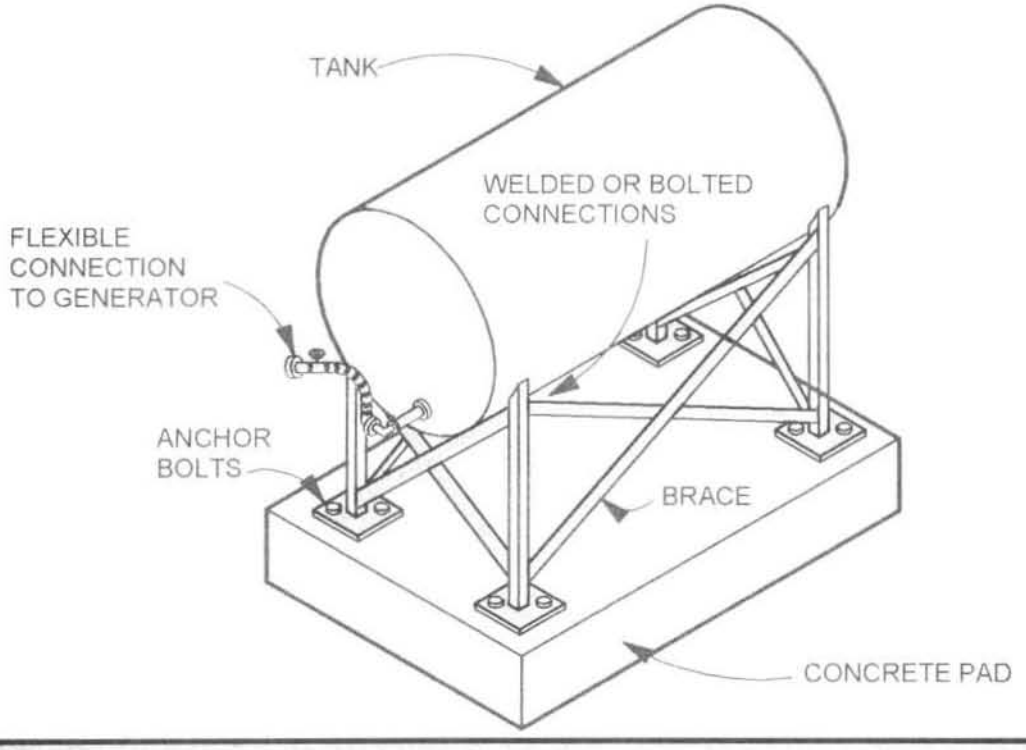
Schematic Upgrade Detail U2
Approximate Cost: $200

U2

DIESEL FUEL TANK

ENGINEERING REQUIRED

Unbraced Day Tank, Hospital, Puerto Rico
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

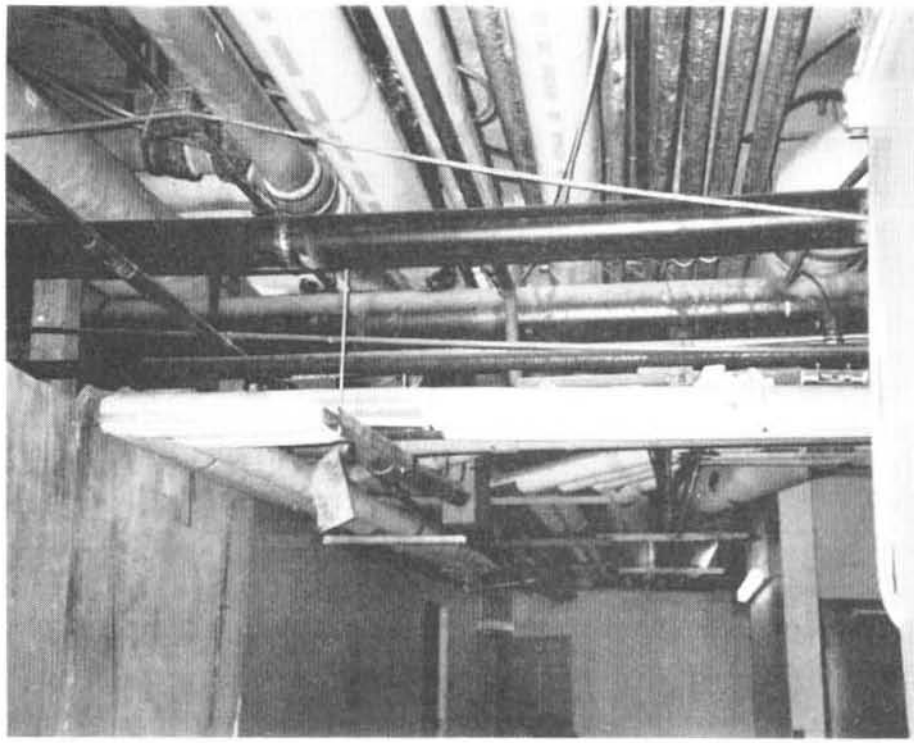


Schematic Upgrade Detail U3
Approximate Cost: $500 - $1000

U3

ELECTRICAL BUS DUCTS AND PRIMARY CABLE SYSTEM

ENGINEERING REQUIRED



Unbraced Overhead Conduit and Pipes
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

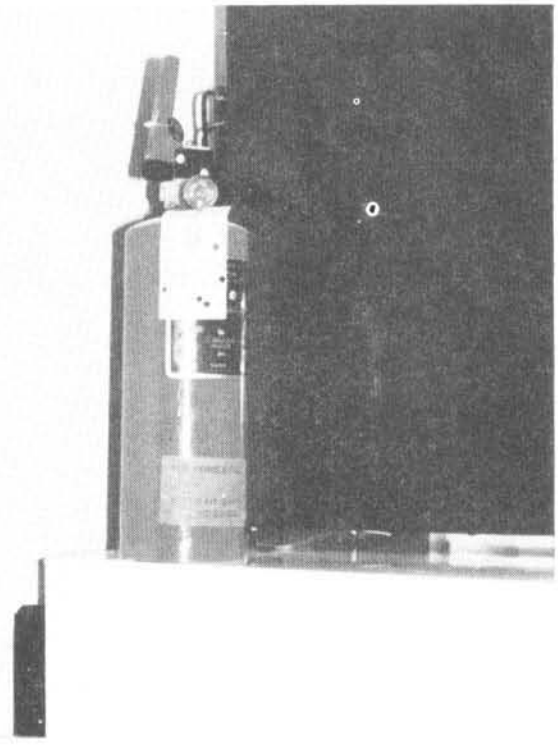
- ELECTRICAL BUS DUCTS AND CABLE LINES SHOULD BE ABLE TO ACCOMMODATE MOVEMENT AT LOCATIONS WHERE THEY CROSS SEISMIC JOINTS BETWEEN BUILDING WINGS. PROVIDE FLEXIBLE CONNECTIONS AT SEISMIC JOINTS.
- PROVIDE FLEXIBLE CONNECTIONS AT LOCATIONS WHERE DUCTS OR CABLE ARE ATTACHED TO RIGIDLY MOUNTED EQUIPMENT.
- DUCTS AND CABLE LINES SHOULD HAVE BOTH TRANSVERSE AND LONGITUDINAL SEISMIC BRACING SIMILAR TO THAT RECOMMENDED FOR PIPING. SEE PIPE BRACING DETAIL U21.

Schematic Upgrade Detail U8
Approximate Cost: $200 - $500 per brace

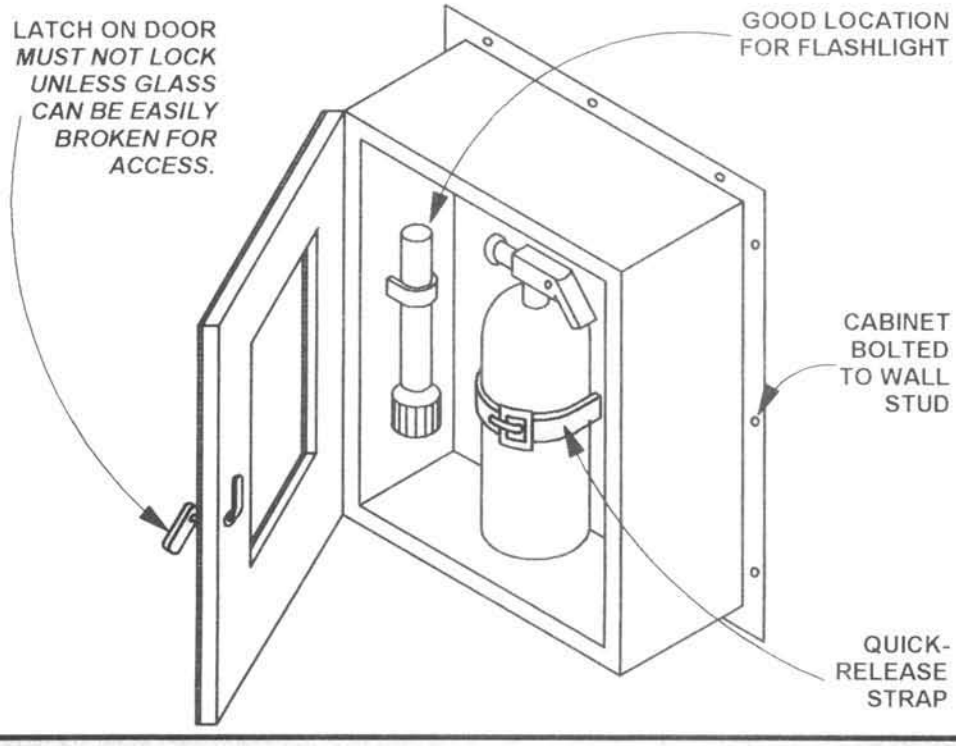
U8

FIRE EXTINGUISHER AND CABINET

DO-IT-YOURSELF



Unrestrained Extinguisher
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

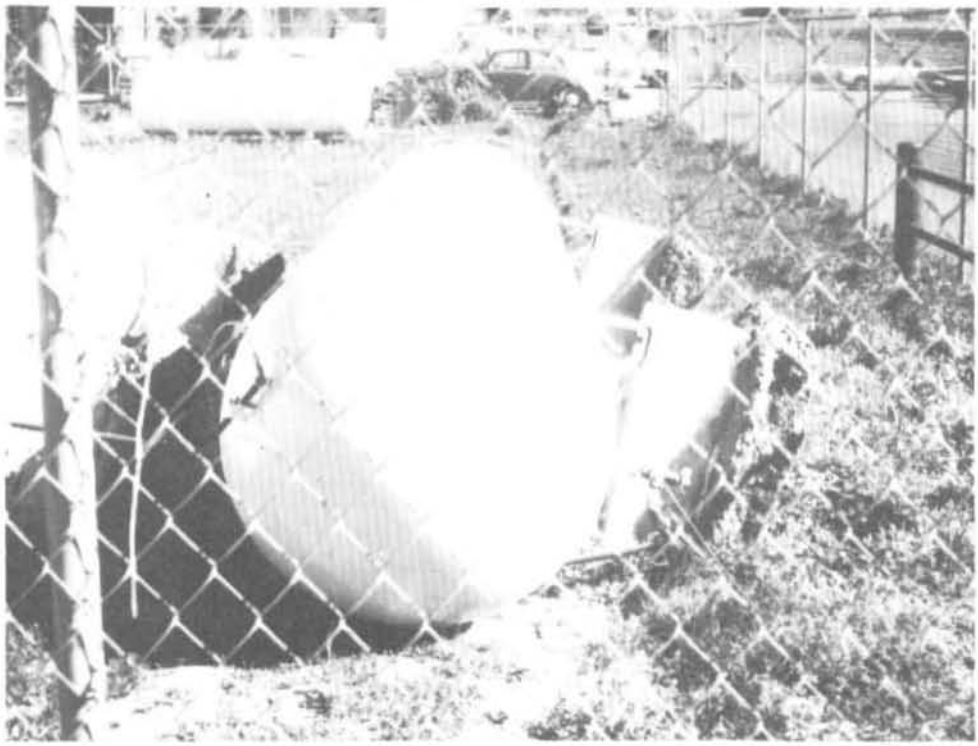


Upgrade Detail U10
Approximate Cost: $300

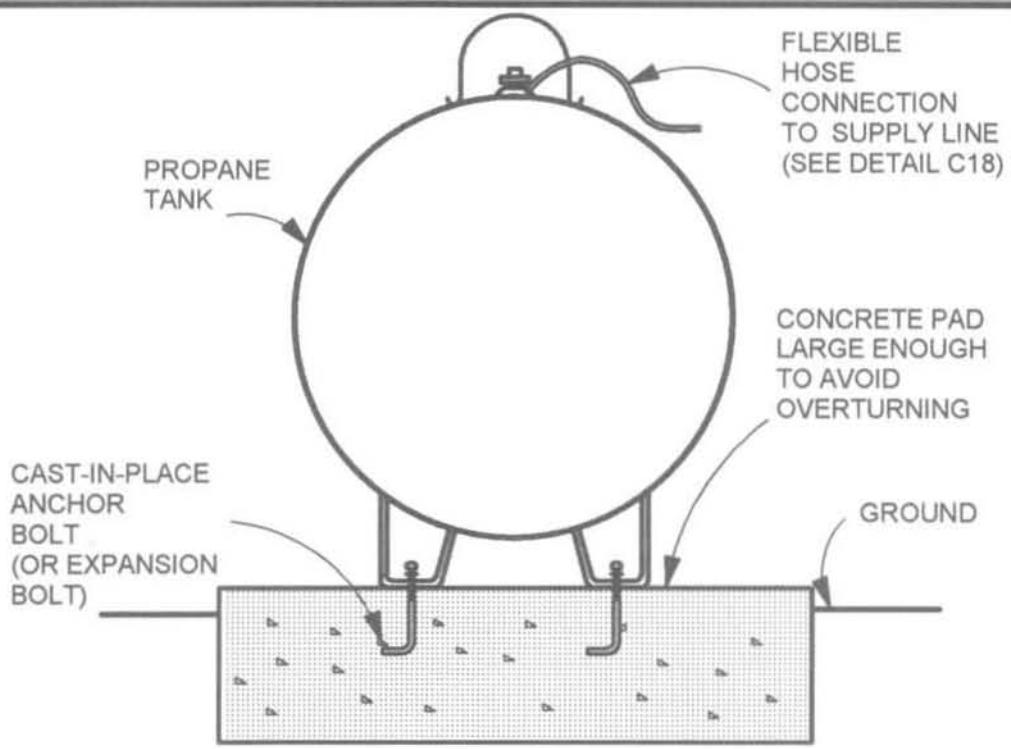
U10

PROPANE TANK

ENGINEERING REQUIRED



Earthquake Damage: 1971, San Fernando, California
Photo Credit: Scientific Service, Inc.

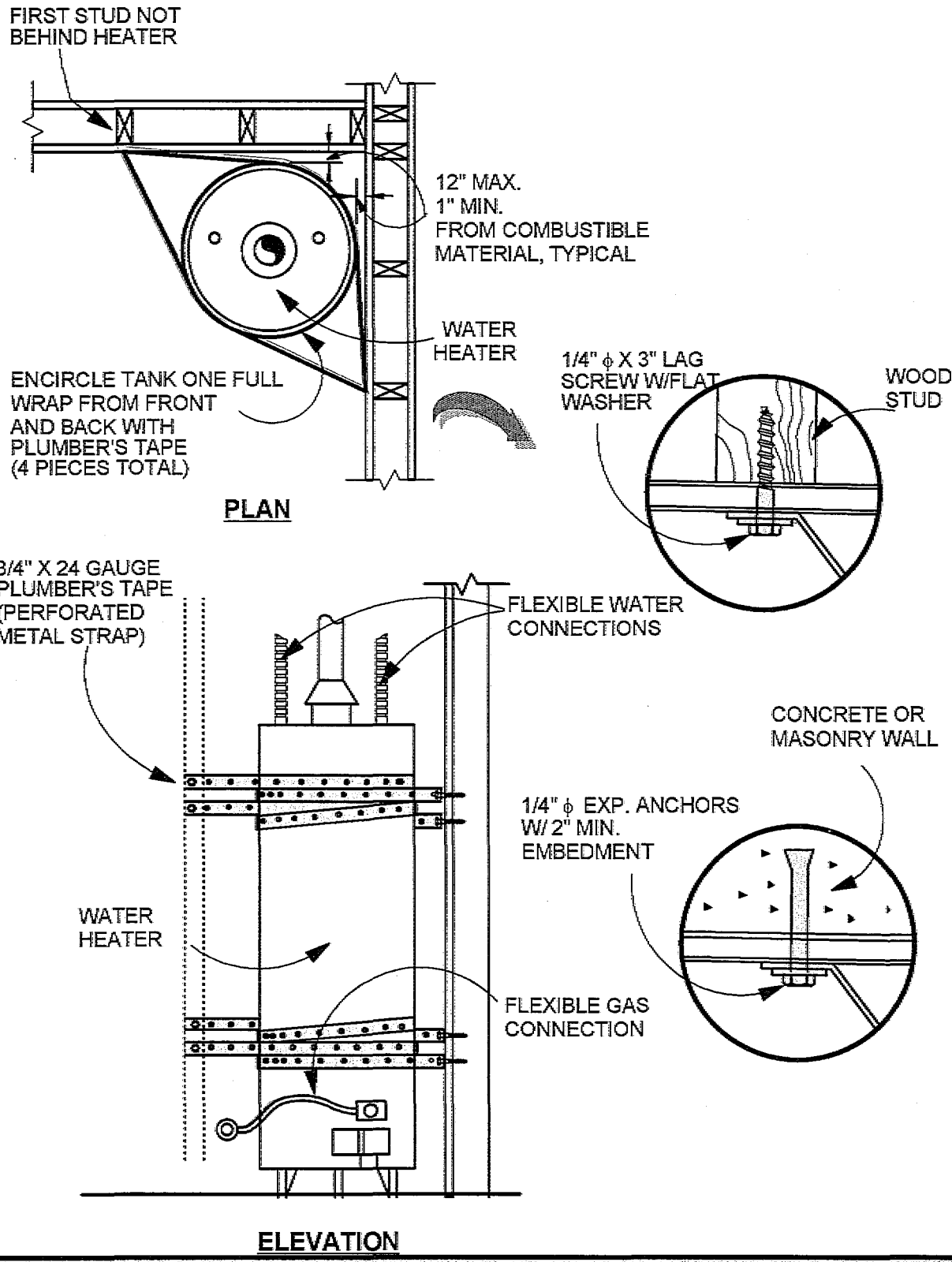


Schematic Upgrade Detail U15
Approximate Cost: $900

U15

WATER HEATER: CORNER INSTALLATION

DO-IT-YOURSELF



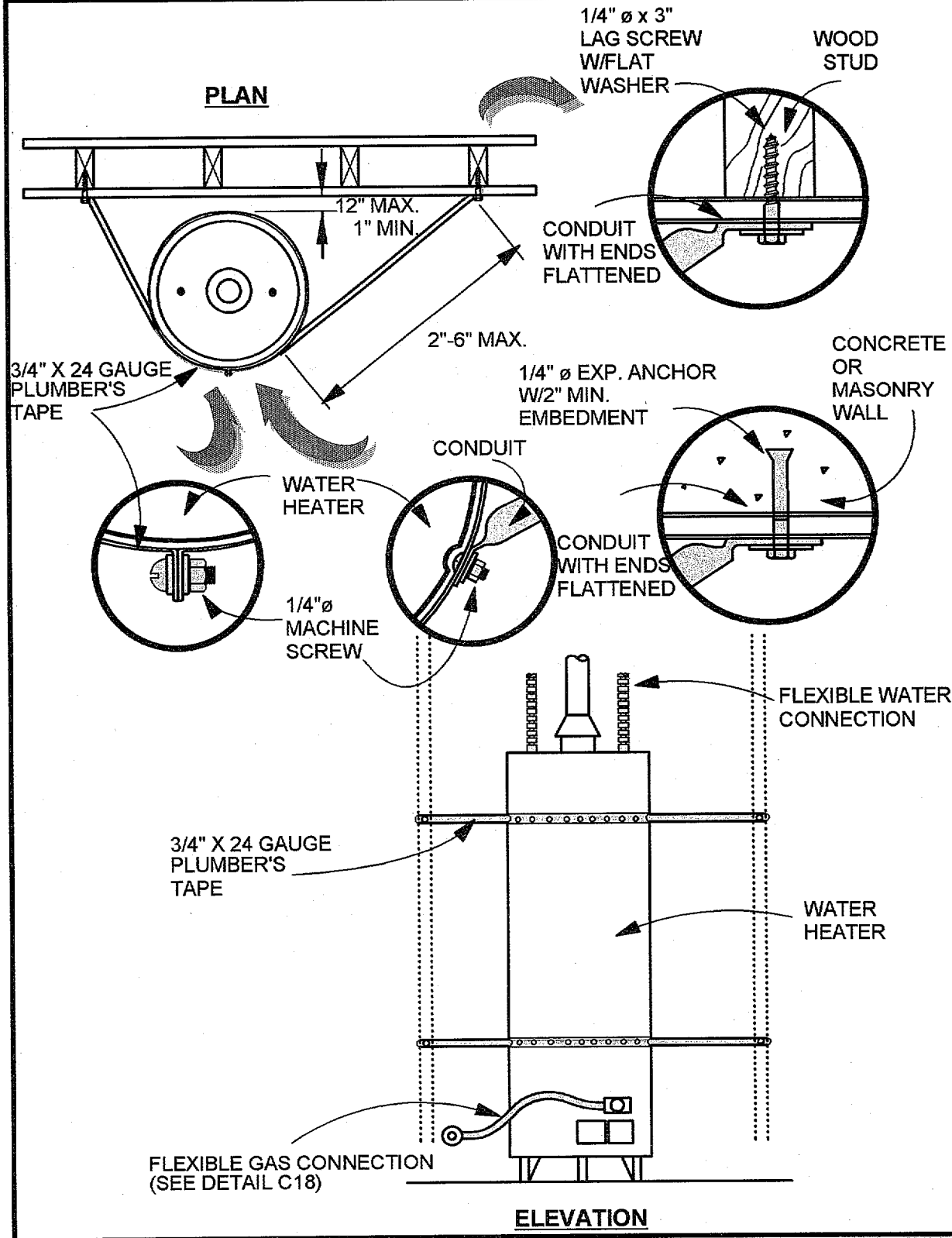
Upgrade Detail U19a

Approximate Cost: $80

U19a

WATER HEATER: WALL INSTALLATION

DO-IT-YOURSELF



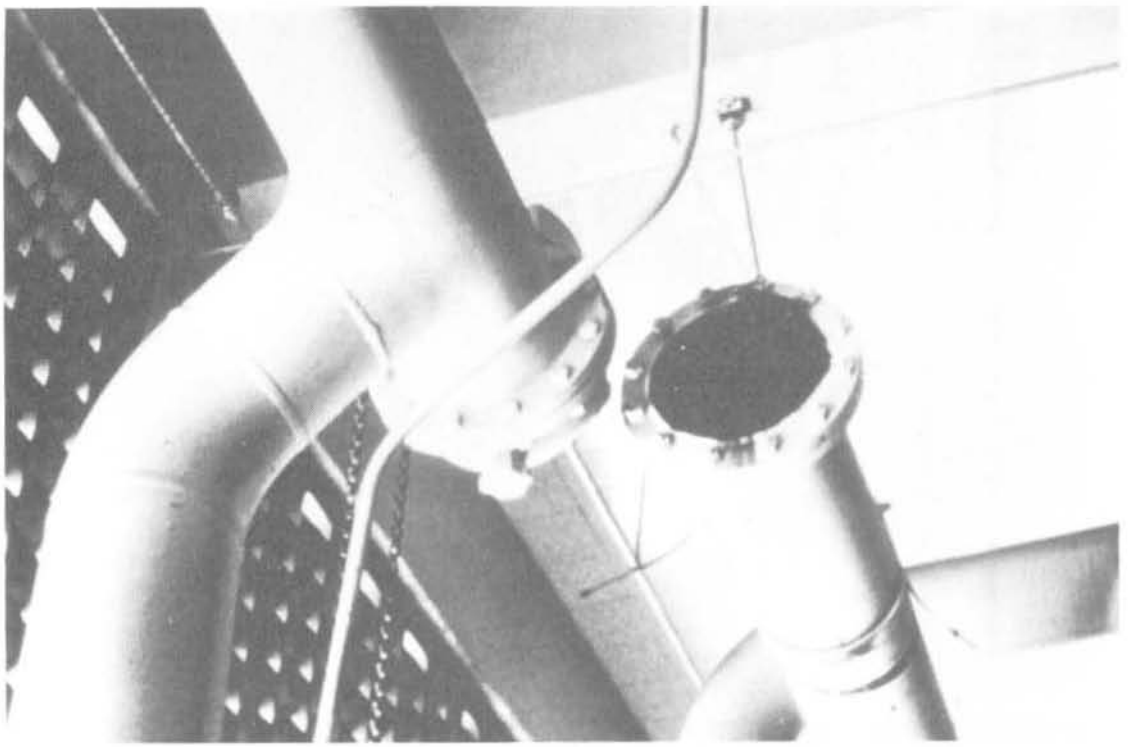
Upgrade Detail U19b

Approximate Cost: $200

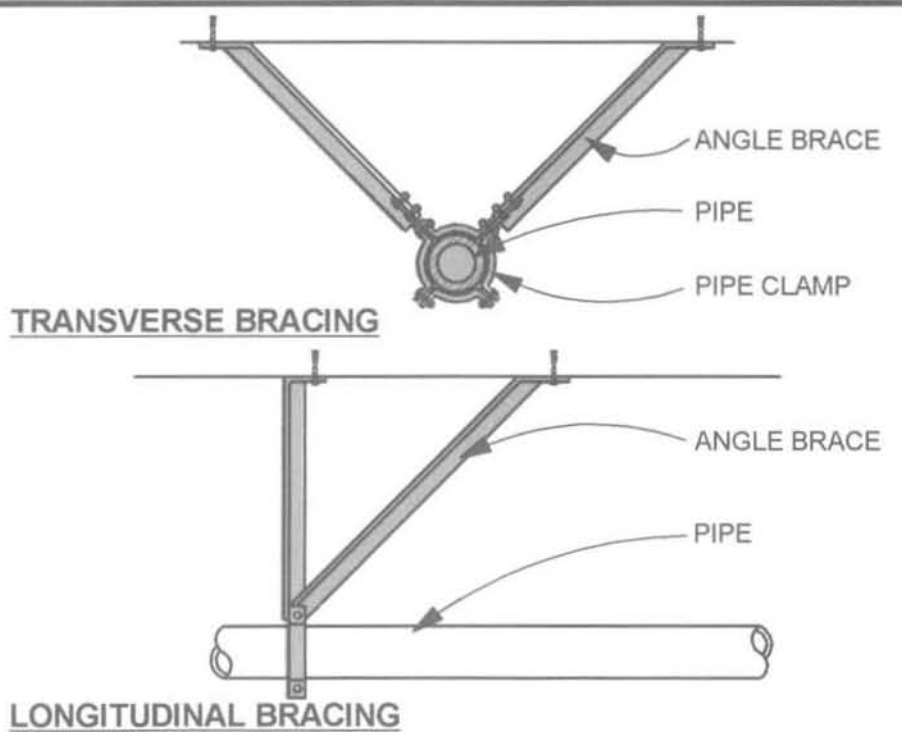
U19b

PIPING

ENGINEERING REQUIRED



Earthquake Damage: 1971, San Fernando, California
Photo Credit: John F. Meehan

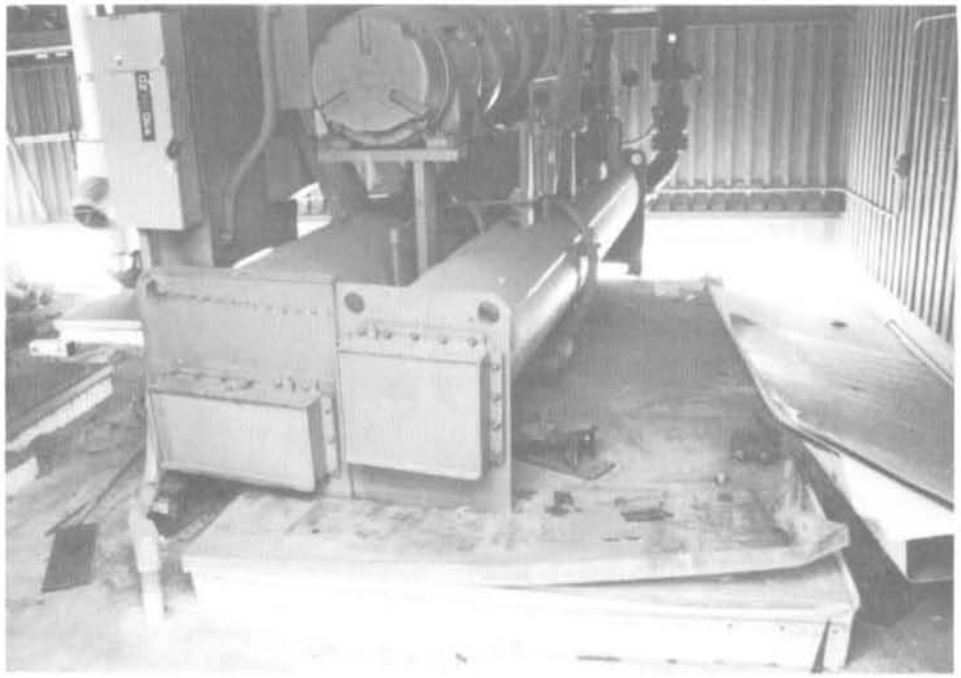


Schematic Upgrade Detail U21
Approximate Cost: $200 - $500 per brace

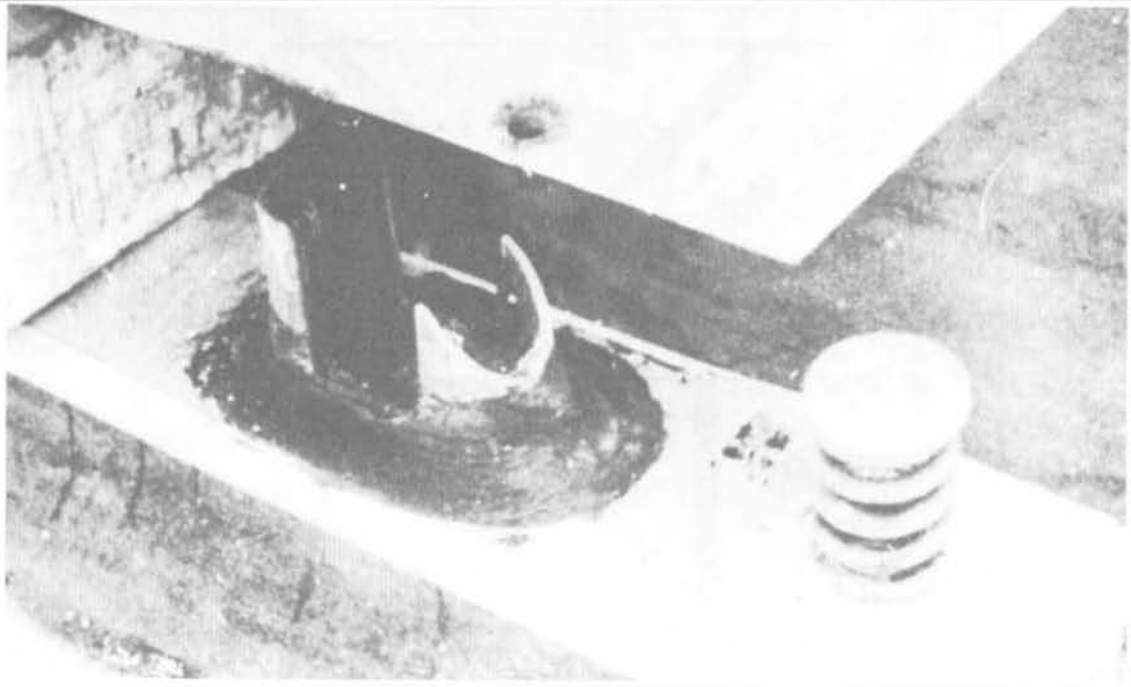
U21

CHILLER

ENGINEERING REQUIRED



Failed chiller mounts due to insufficient uplift resistance.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



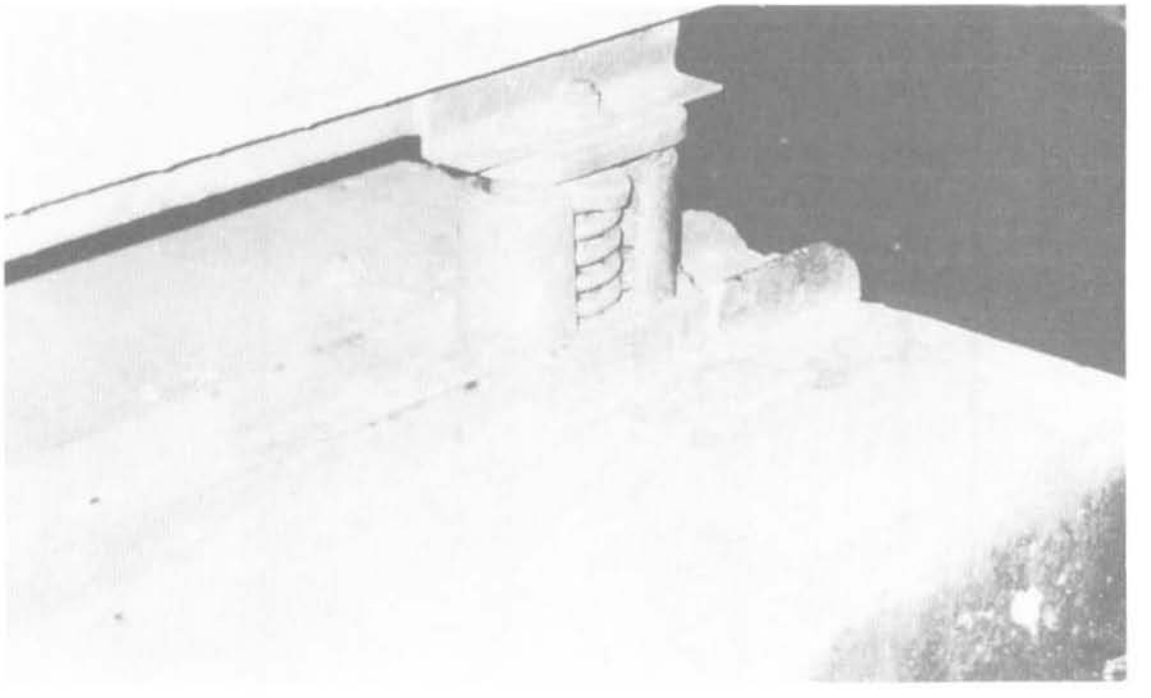
Failed chiller due mount due to insufficient shear resistance.
Earthquake Damage: 1980, Livermore, California
Photo Credit: William T. Holmes

Schematic Upgrade Detail: See Detail U32, Air Compressor

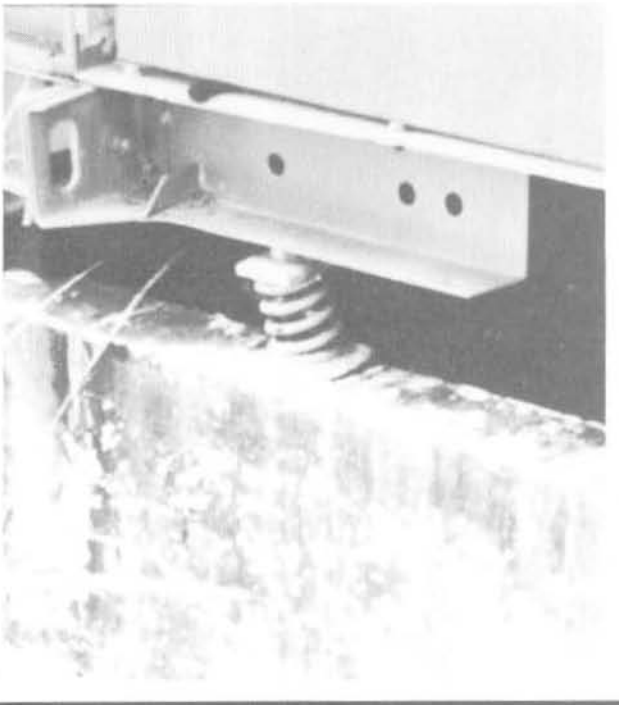
U29a

CHILLER

ENGINEERING REQUIRED



Chiller mount with no uplift resistance and insufficient shear resistance.
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Chiller mount with no uplift resistance and insufficient or no shear resistance.
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

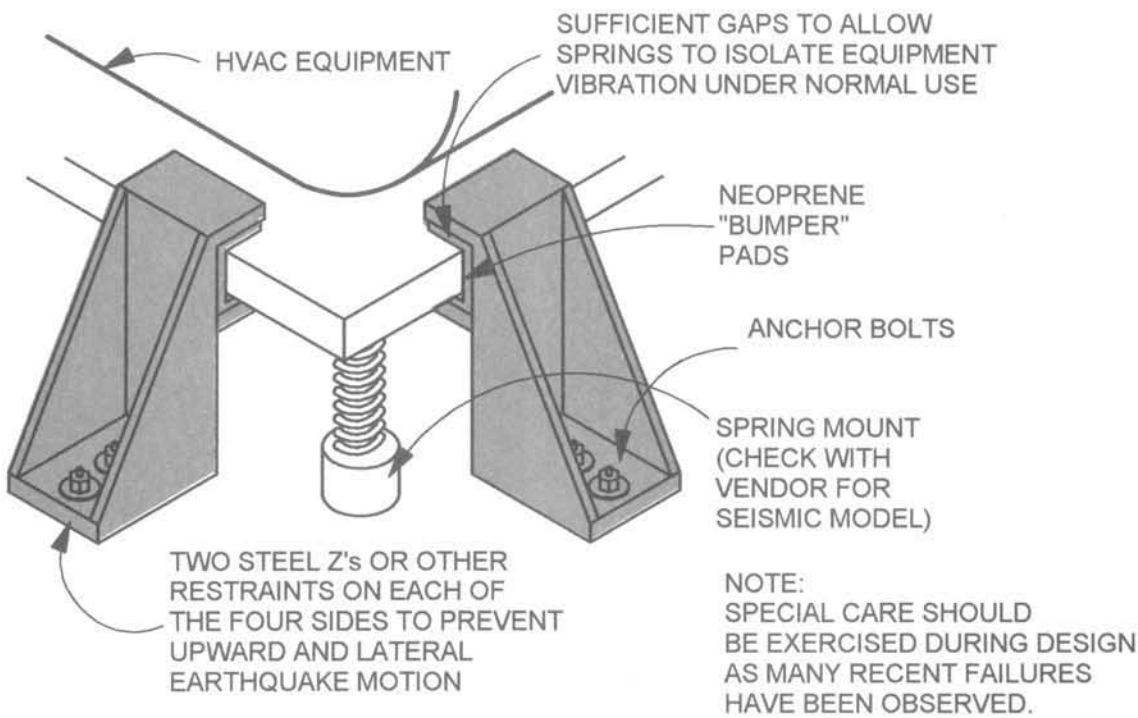
Schematic Upgrade Detail: See Detail U32, Air Compressor

U29b

AIR COMPRESSOR (OR OTHER HVAC EQUIPMENT)

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

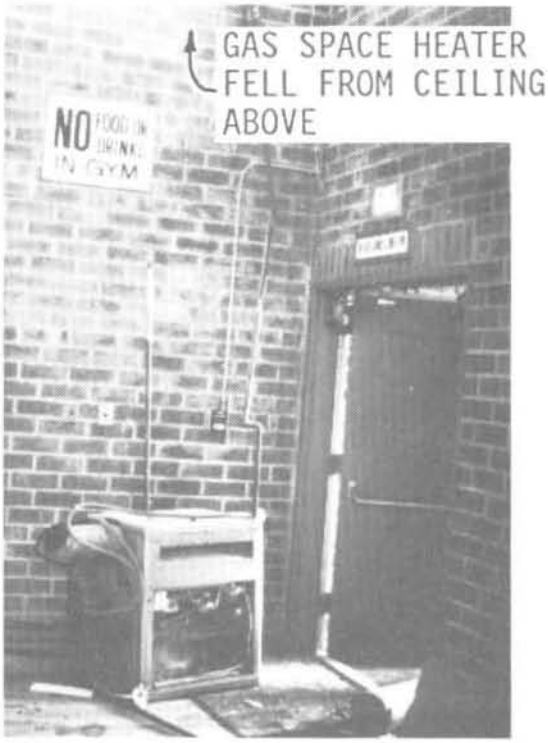


Schematic Upgrade Detail U32
Approximate Cost: Depends on individual case; $300 - $1,200

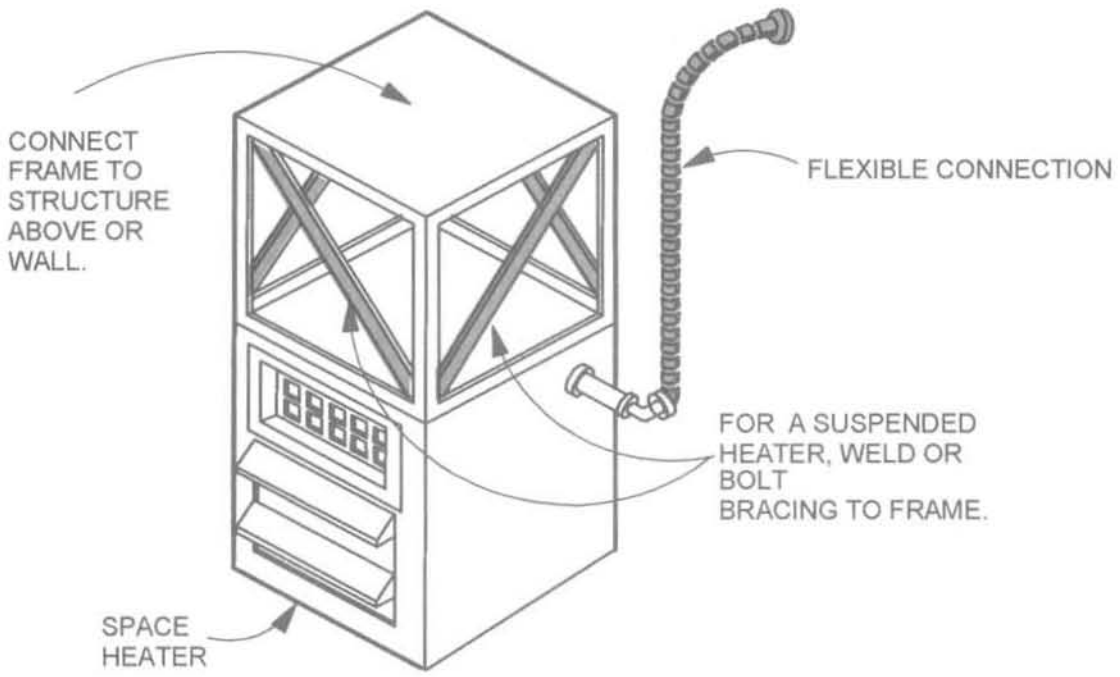
U32

SUSPENDED SPACE HEATER

ENGINEERING REQUIRED



Earthquake Damage: 1971, San Fernando, California
Photo Credit: C. Wilton, Scientific Service, Inc.

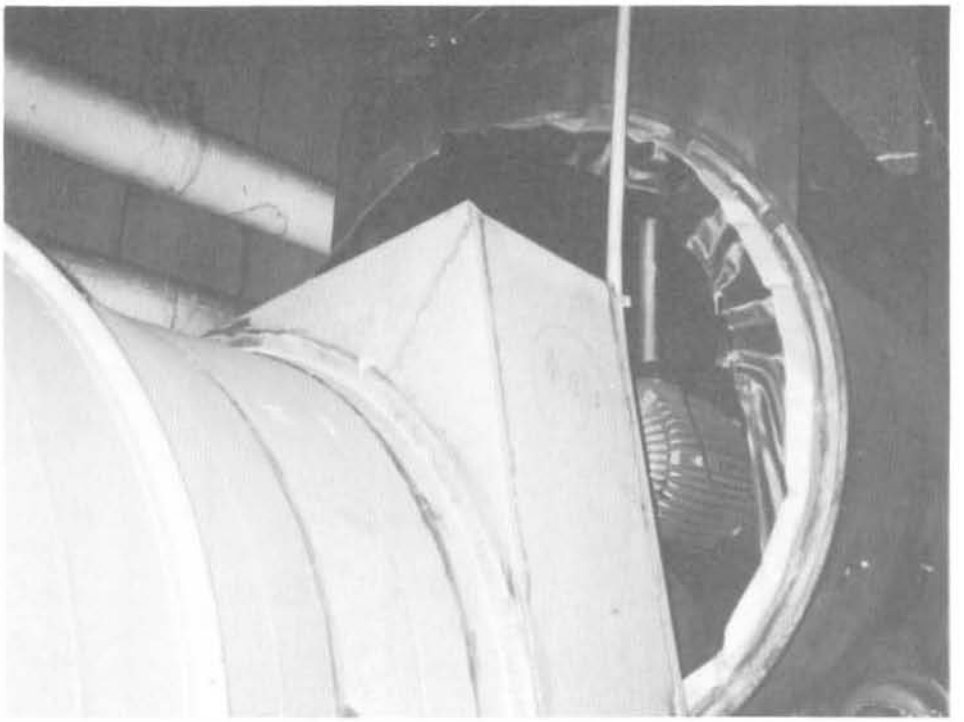


Schematic Upgrade Detail U35
Approximate Cost: $200

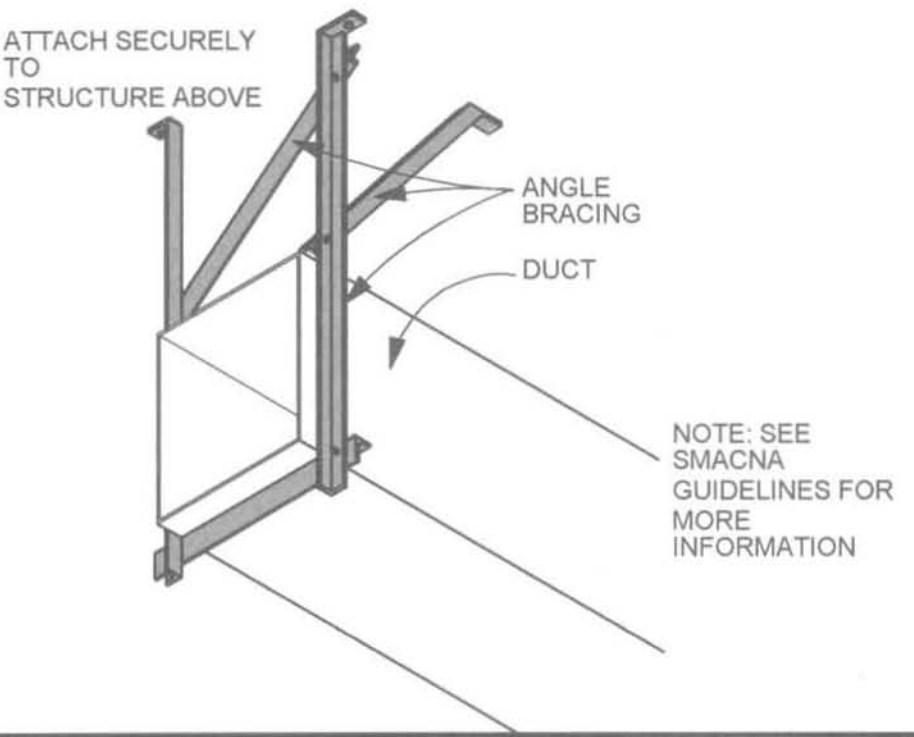
U35

HVAC DISTRIBUTION DUCTS

ENGINEERING REQUIRED



Sheet metal duct separated from fan unit.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



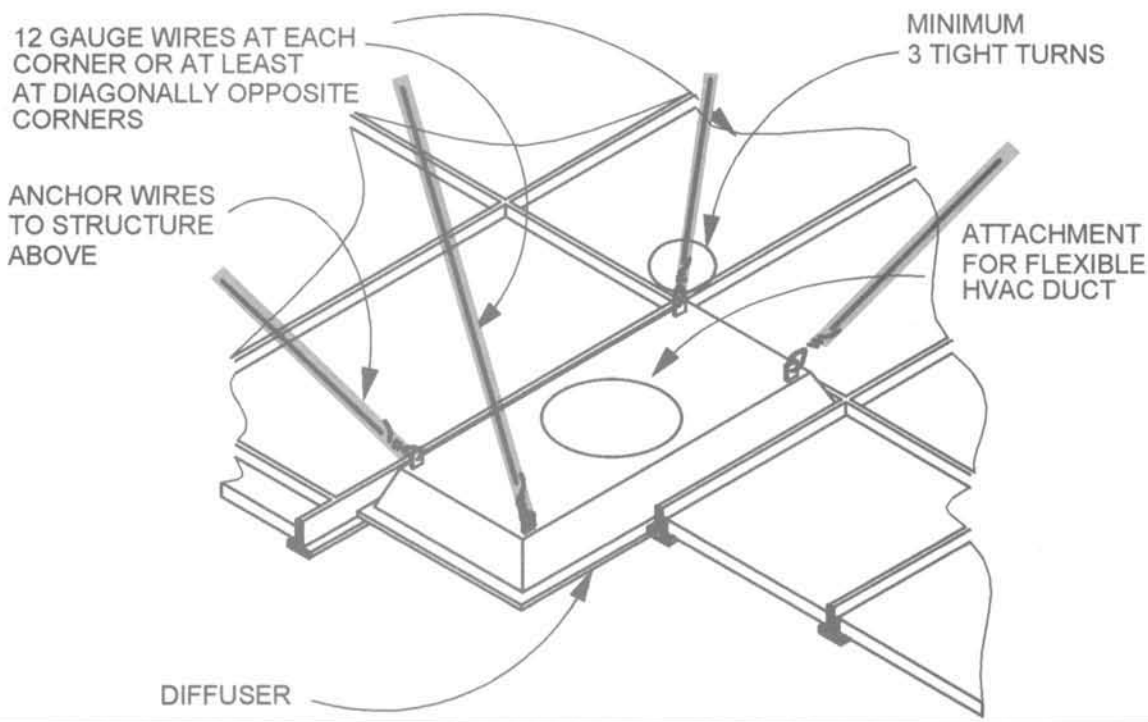
Schematic Upgrade Detail U36
Approximate Cost: $200 - $500 per support

U36

AIR DIFFUSER

DO-IT-YOURSELF

Air diffusers fell to the floor.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc



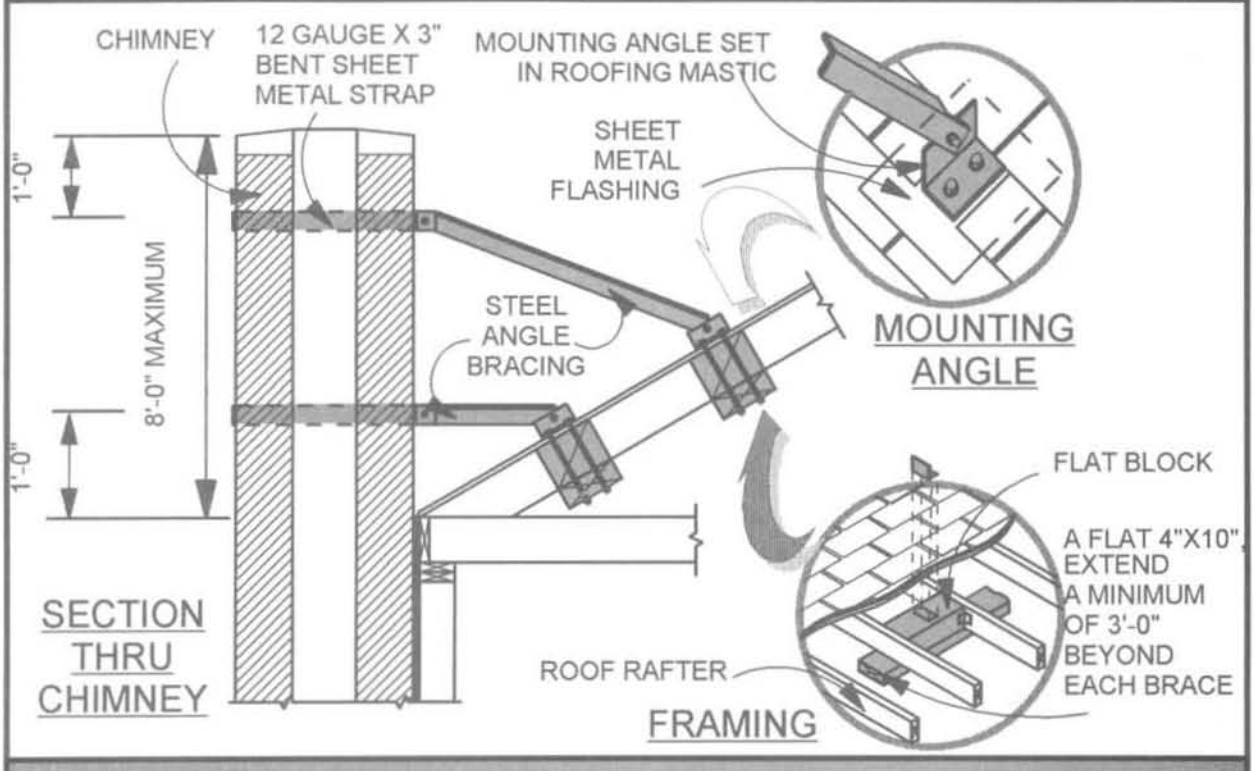
Upgrade Detail U37
Approximate Cost: $50

U37

RESIDENTIAL CHIMNEY

ENGINEERING REQUIRED

Earthquake Damage: 1989, Loma Prieta, California
Photo Credit: California Office of Emergency Services, Earthquake Program



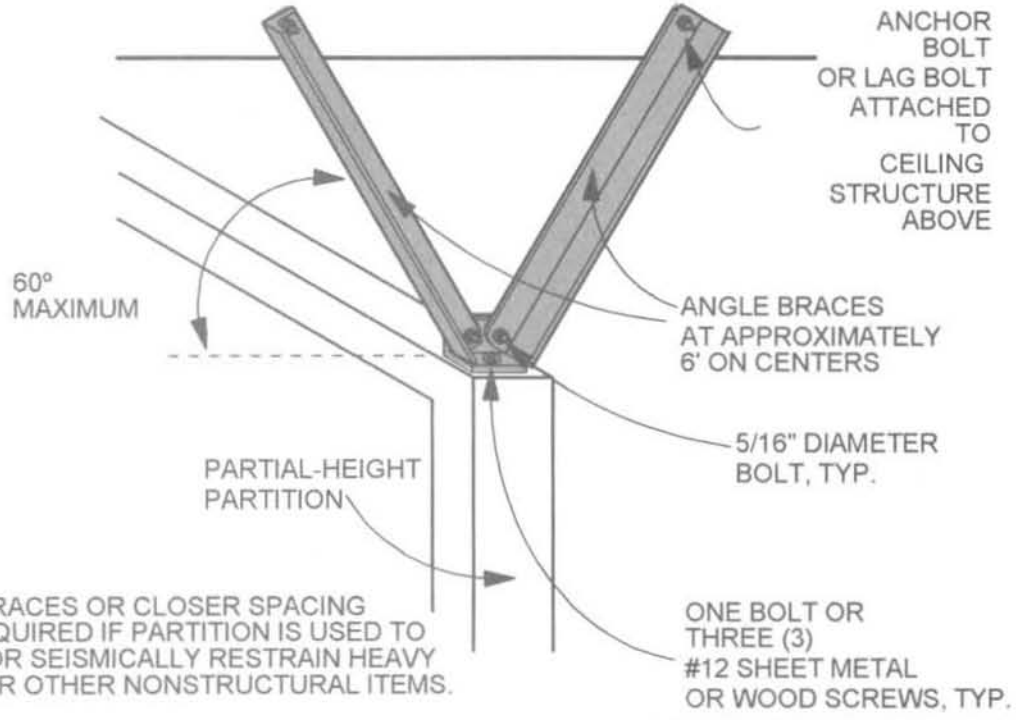
Upgrade Detail U38 (Recommended only for areas of low to moderate seismicity).
Approximate Cost: $1,000

U38

BUILT-IN PARTIAL-HEIGHT PARTITIONS

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



- HEAVIER BRACES OR CLOSER SPACING MAY BE REQUIRED IF PARTITION IS USED TO SUPPORT OR SEISMICALLY RESTRAIN HEAVY SHELVES OR OTHER NONSTRUCTURAL ITEMS.

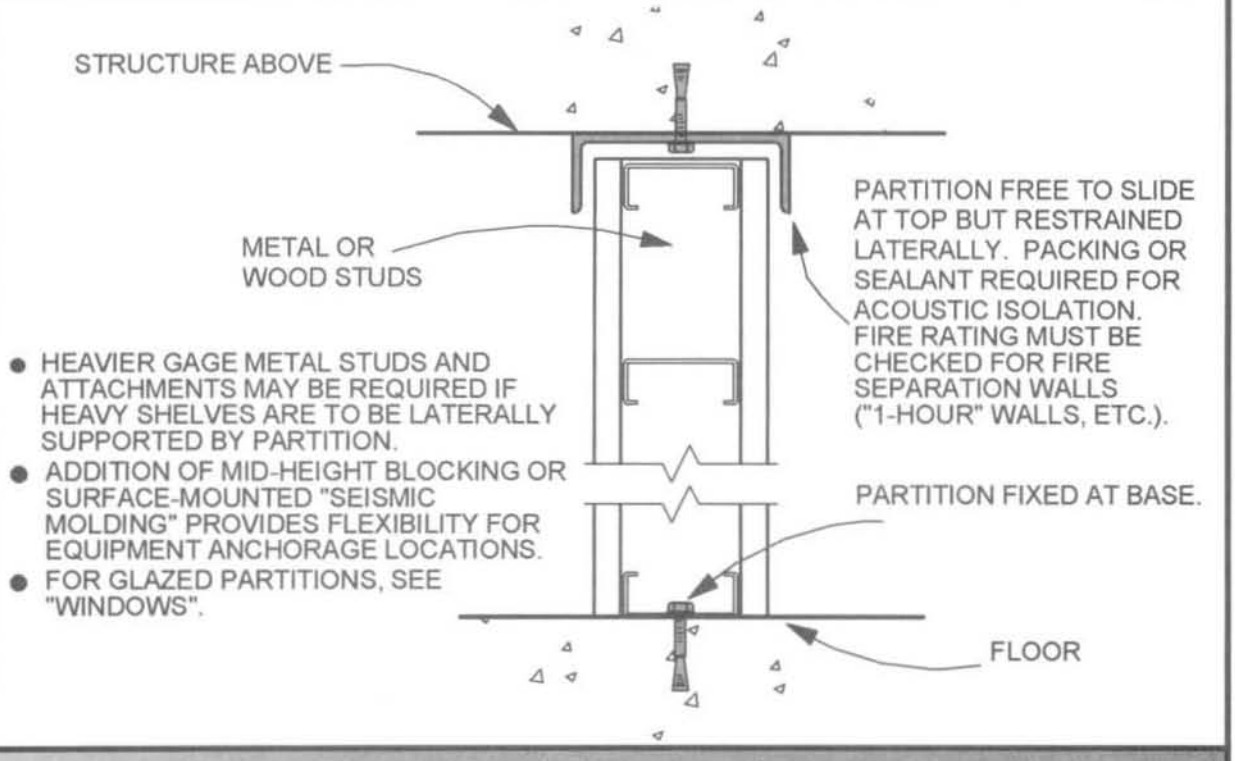
Schematic Upgrade Detail A2a
Approximate Cost: Varies - $20 - $40 per lineal foot

A2a

BUILT-IN FULL-HEIGHT PARTITIONS

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



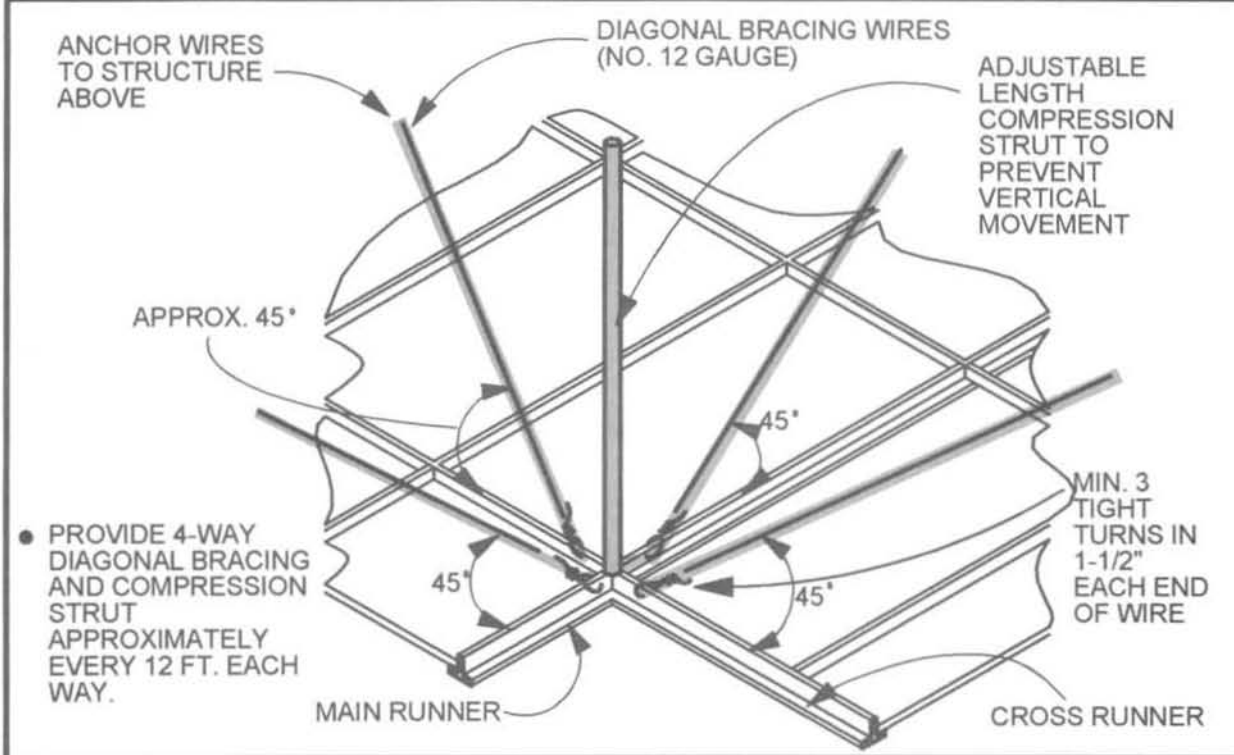
Schematic Upgrade Detail A2b
Approximate Cost: Varies, depending on design

A2b

SUSPENDED T-BAR CEILINGS

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

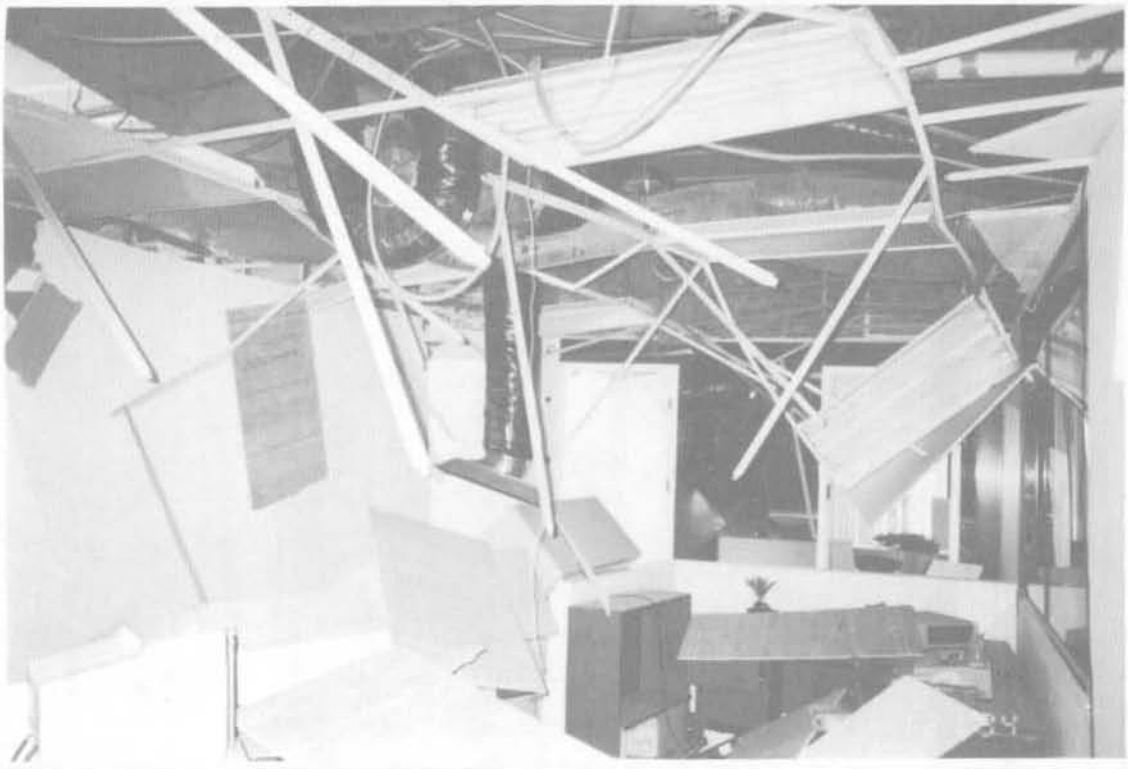


Schematic Upgrade Detail A3
Approximate Cost: $50 per brace

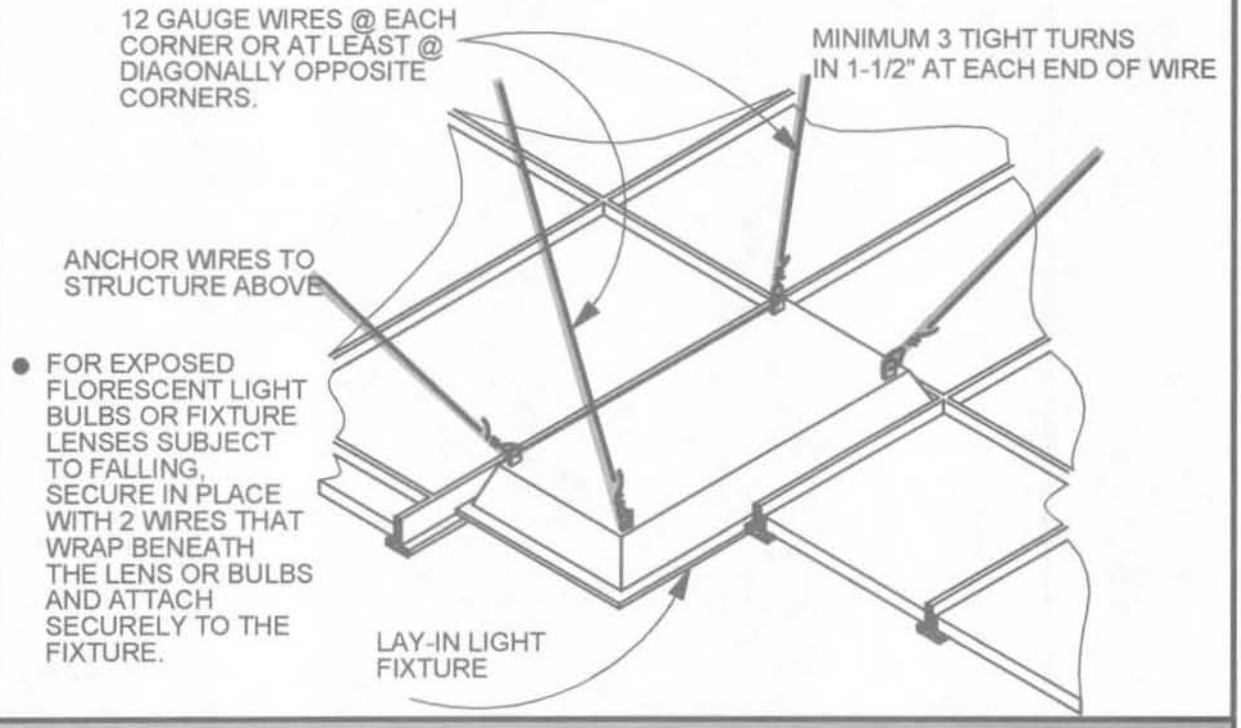
A3

SUSPENDED LIGHT FIXTURES

DO-IT-YOURSELF



Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

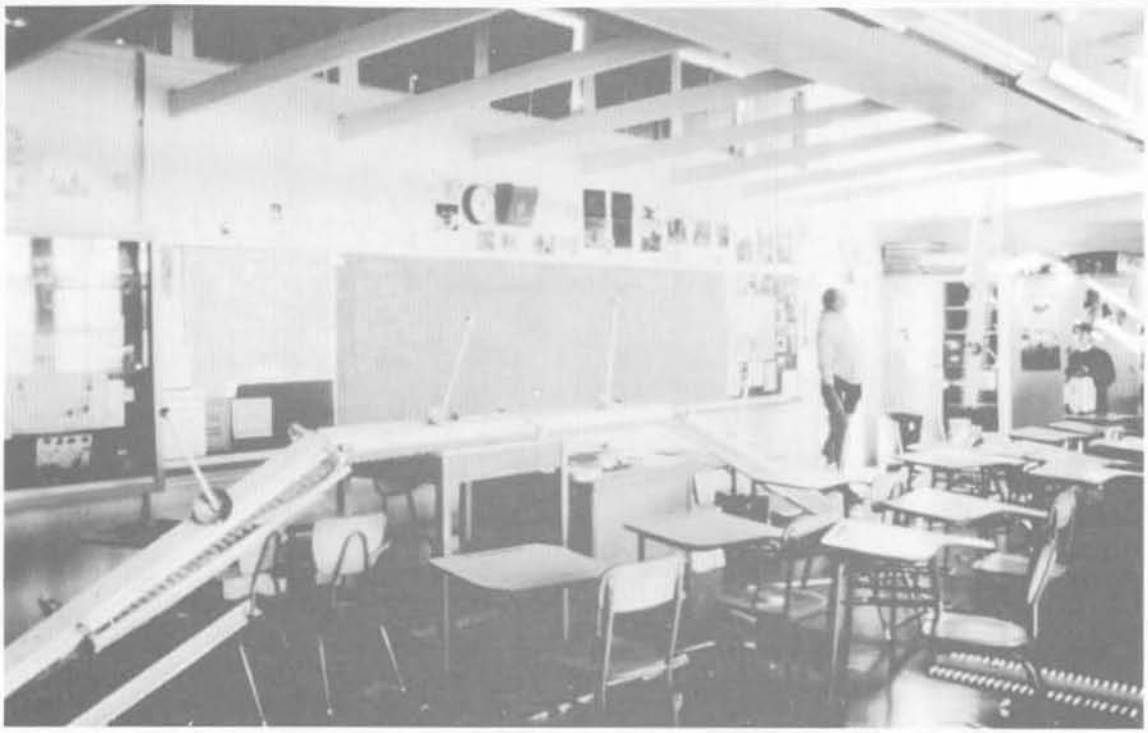


Upgrade Detail U5a
Approximate Cost: $50 per fixture

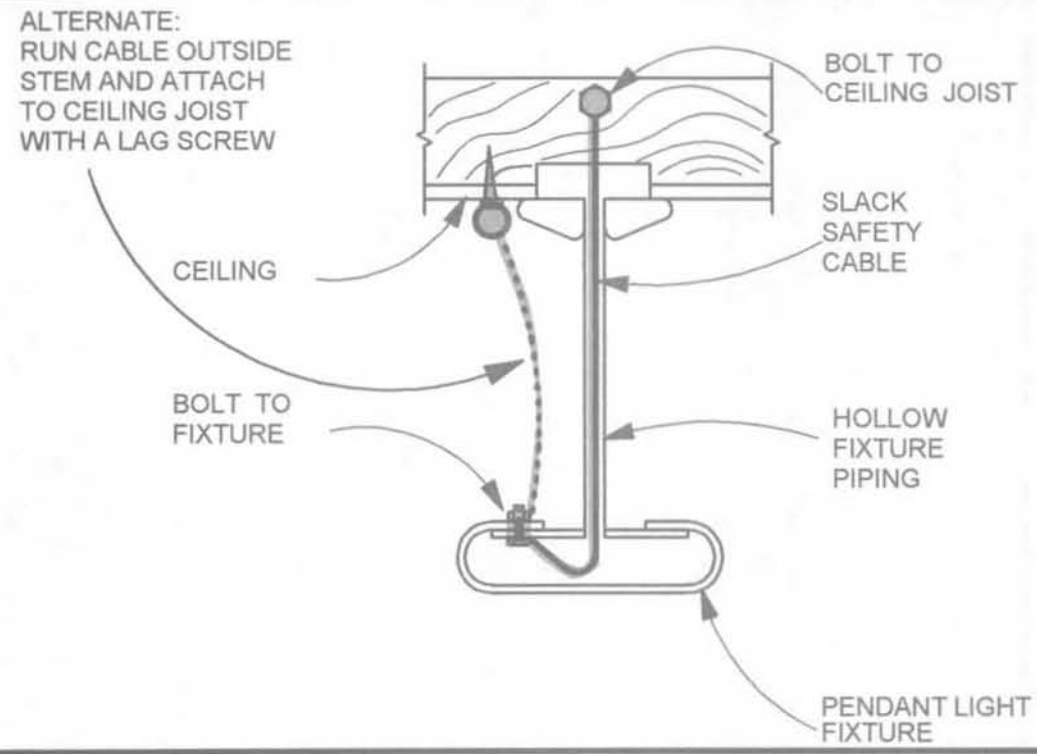
A5a

PENDANT LIGHT FIXTURES

DO-IT-YOURSELF



Failure of light fixtures at Northridge Junior High School
Earthquake Damage: 1994, Northridge, California
Photo Credit: Earthquake Engineering Research Institute, Gary L. McGavin



Upgrade Detail A5b
Approximate Cost: $80

A5b

STAIRWAYS

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

- TO PREVENT DAMAGE TO STAIRS THEY SHOULD BE MODIFIED TO ALLOW THEM TO SLIDE AT LANDINGS WITH "GANG PLANK" DETAILS; THIS IS DESIRABLE FOR FLEXIBLE FRAME BUILDINGS.
- IF STAIR ENCLOSURES ARE CONSTRUCTED USING BRITTLE MATERIALS, SUCH AS, HOLLOW CLAY TILE, GLASS BLOCK PARTITIONS, OR SKYLIGHTS, IT IS RECOMMENDED THAT THEY BE ENCAPSULATED OR REPLACED TO PREVENT FALLING HAZARDS AND DEBRIS IN THE STAIRWELL.
- PROVIDE ANCHORAGE FOR PIPES, LIGHTING OR DUCTS IN STAIRWELLS TO PREVENT FALLING HAZARDS AND DEBRIS.

Schematic Upgrade Detail A9
Approximate Cost: Depends on design

A9

WINDOWS

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

- USE OF TEMPERED GLASS WILL GREATLY REDUCE THE SEISMIC HAZARD. TEMPERED GLASS MAY STILL BREAK, BUT WILL BREAK INTO SMALL DULL FRAGMENTS INSTEAD OF LARGE DANGEROUS SHARDS.
- POLYESTER SHATTER RESISTANT FILMS ARE AVAILABLE THAT HELP HOLD TOGETHER FRAGMENTS OF ANY PANES THAT CRACK IN AN EARTHQUAKE. (TYPICAL SOLAR FILM MAY NOT BE ADEQUATE FOR THIS PURPOSE).
- USE OF LAMINATED GLASS FOR STOREFRONTS REDUCES SEISMIC RISK AND ALSO INCREASES PROTECTION FROM BURGLARY OR VANDALISM.
- SMALLER, OPERABLE, AND WOODEN FRAMED WINDOWS TOLERATE MORE LATERAL DRIFT.
- FOR NEW CONSTRUCTION, STIFFER BUILDINGS AND GLAZING WITH MORE THAN THE STANDARD EDGE CLEARANCES MAY BE DESIRABLE. CHECK WHETHER OR NOT THE BUILDING'S CALCULATED SEISMIC DRIFT HAS BEEN CONSIDERED IN THE DESIGN OF THE GLAZING.

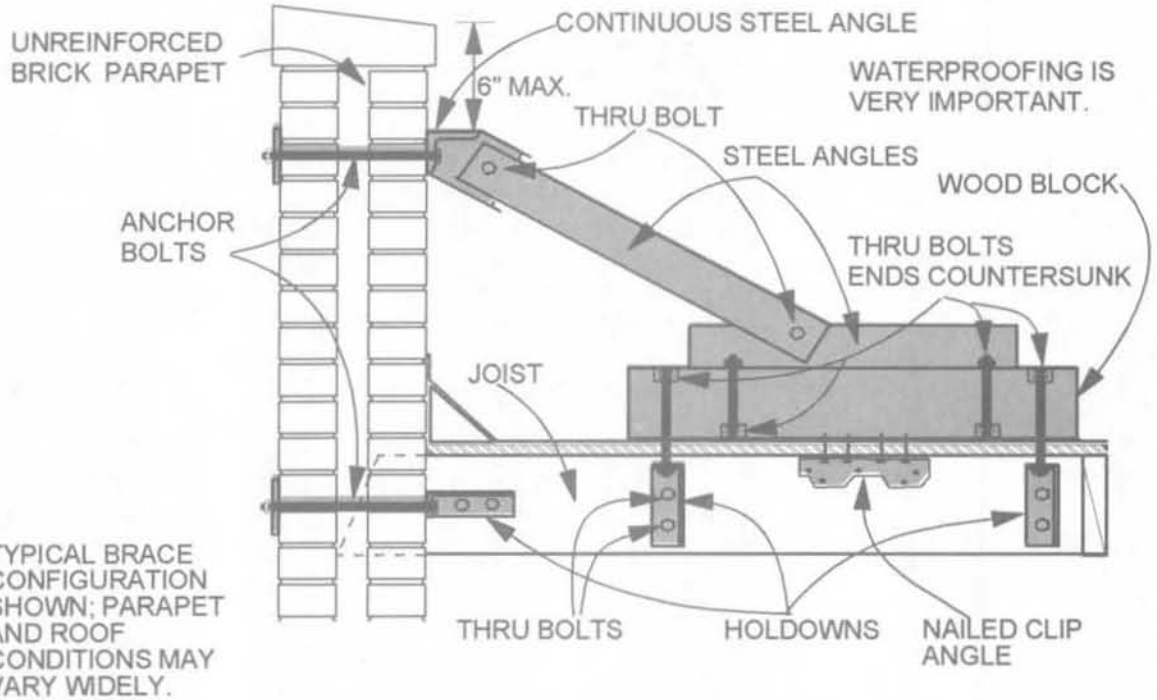
Schematic Upgrade Detail A12
Approximate Cost: Depends on design

A12

UNREINFORCED BRICK PARAPETS

ENGINEERING REQUIRED

Earthquake Damage: 1989, Loma Prieta, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



- TYPICAL BRACE CONFIGURATION SHOWN; PARAPET AND ROOF CONDITIONS MAY VARY WIDELY.

Schematic Upgrade Detail A15a
Approximate Cost: $50 per foot

A15a

VENEER

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Robert Reitherman

- SEE APPLICABLE BUILDING CODE REQUIREMENTS FOR LIMITATIONS REGARDING THE HEIGHT, AREA, UNIT SIZE, AND UNIT WEIGHT OF EITHER ADHERED OR ANCHORED VENEER SYSTEMS. REFER TO THE CODE SECTIONS FOR SPECIFIC REQUIREMENTS FOR BACKING, TIES, AND REINFORCEMENT. (FOR EXAMPLE, SECTION 1403 OF THE 1994 UBC).

- VENEER SYSTEMS MUST ALSO AT LEAST MEET THE MINIMUM LATERAL FORCE REQUIREMENTS FOR NONSTRUCTURAL COMPONENTS. (FOR EXAMPLE, THE REQUIREMENTS FOR EXTERIOR AND INTERIOR ORNAMENTATION AND APPENDAGES IN CHAPTER 16 OF THE 1994 UBC).

- REMOVAL OF VENEER MOUNTED OVER ENTRANCES OR OTHER POTENTIALLY CROWDED LOCATIONS IS THE MOST RELIABLE UPGRADE SOLUTION.

Schematic Upgrade Detail A15b
Approximate Cost: Varies

A15b

FREESTANDING WALLS OR FENCES

ENGINEERING REQUIRED

Earthquake Damage: 1994, Northridge, California
Photo Credit: Robert Reitherman

- MANY MILES OF POORLY CONSTRUCTED CONCRETE MASONRY UNIT (CMU) FENCES WERE DAMAGED DURING THE 1994 NORTHRIDGE EARTHQUAKE. COLLAPSE OF WALLS WITH INADEQUATE OR ABSENT REINFORCING AND/OR FOUNDATIONS WAS COMMON IN NORTHRIDGE AND SYLMAR. IN MANY CASES, MOST OF THE SIDEWALK WAS COVERED WITH DEBRIS, AS SHOWN ABOVE.
- FREESTANDING WALLS OR FENCES BUILT OF CMU, BRICK, OR STONE NEED TO BE ENGINEERED AND CONSTRUCTED WITH APPROPRIATE FOUNDATIONS, ADEQUATE REINFORCEMENT, AND GOOD QUALITY MORTAR.
- STANDARD DETAILS FOR LOW FENCES OR SHORT RETAINING WALLS MAY BE AVAILABLE FROM THE LOCAL BUILDING DEPARTMENT.

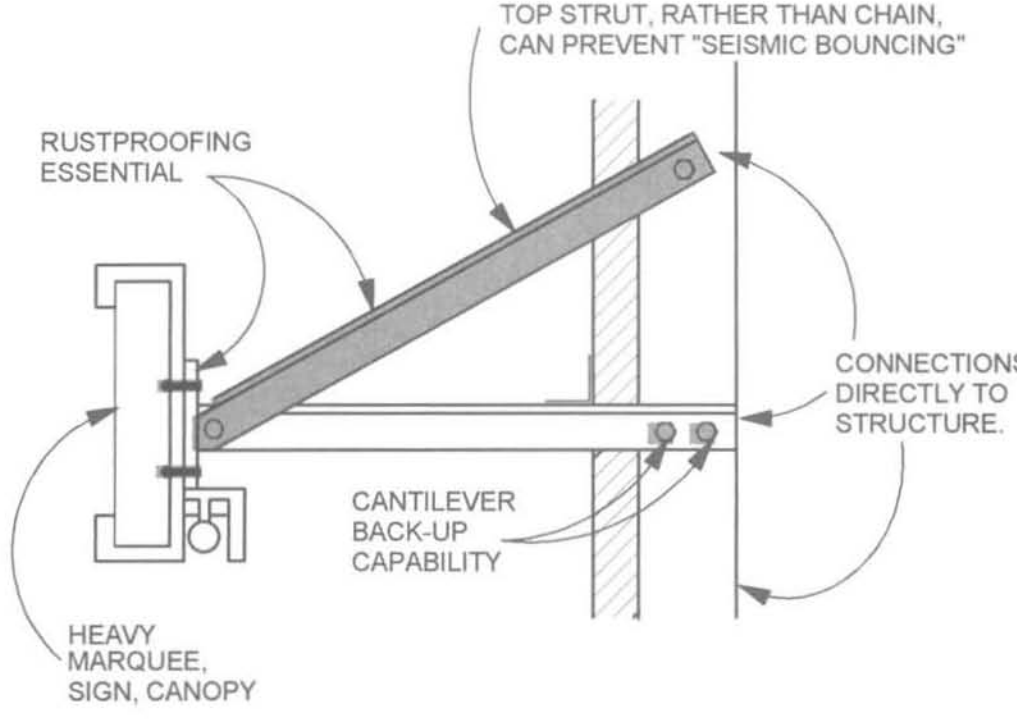
Schematic Upgrade Detail A16
Approximate Cost: Depends on the design

A16

EXTERIOR SIGNS

ENGINEERING REQUIRED

Earthquake Damage: 1979, Imperial Valley, California
Photo Credit: Robert Reitherman/BSD, Inc.

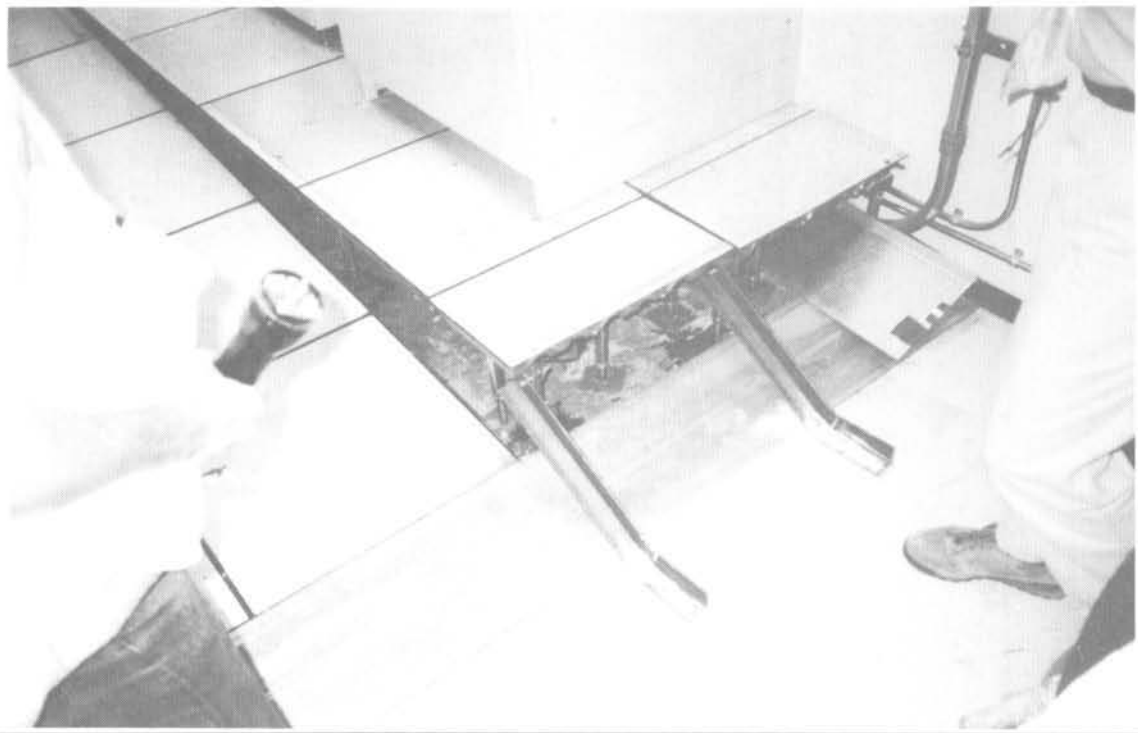


Schematic Upgrade Detail A21
Approximate Cost: $500 - $800

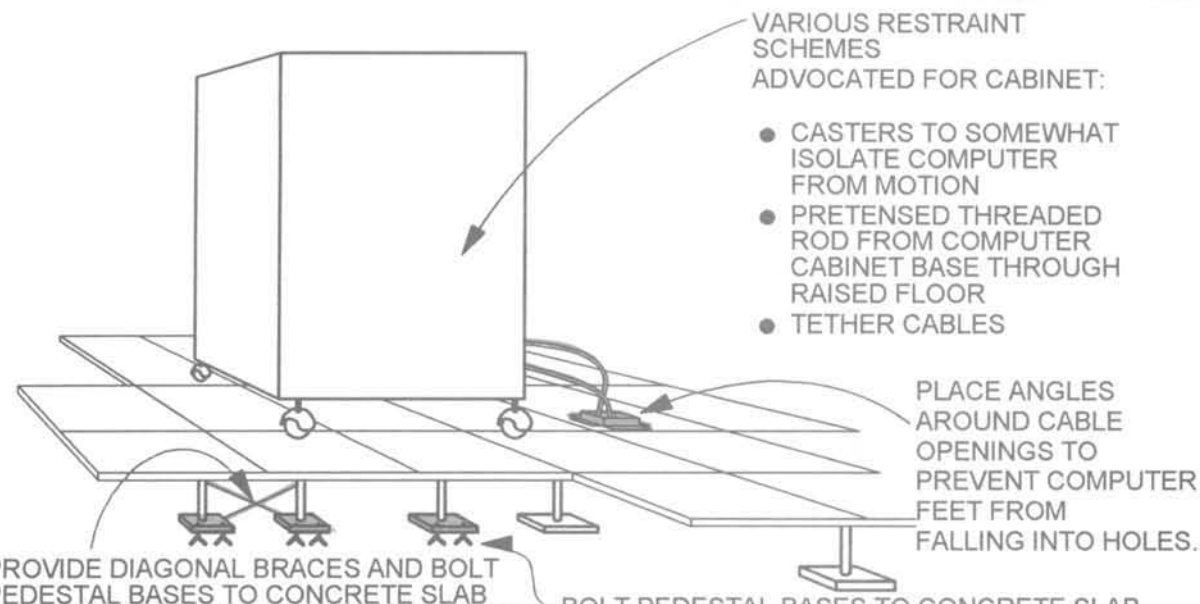
A21

LARGE COMPUTERS AND ACCESS FLOORS

ENGINEERING REQUIRED



Temporary bracing for collapsed access floor
Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



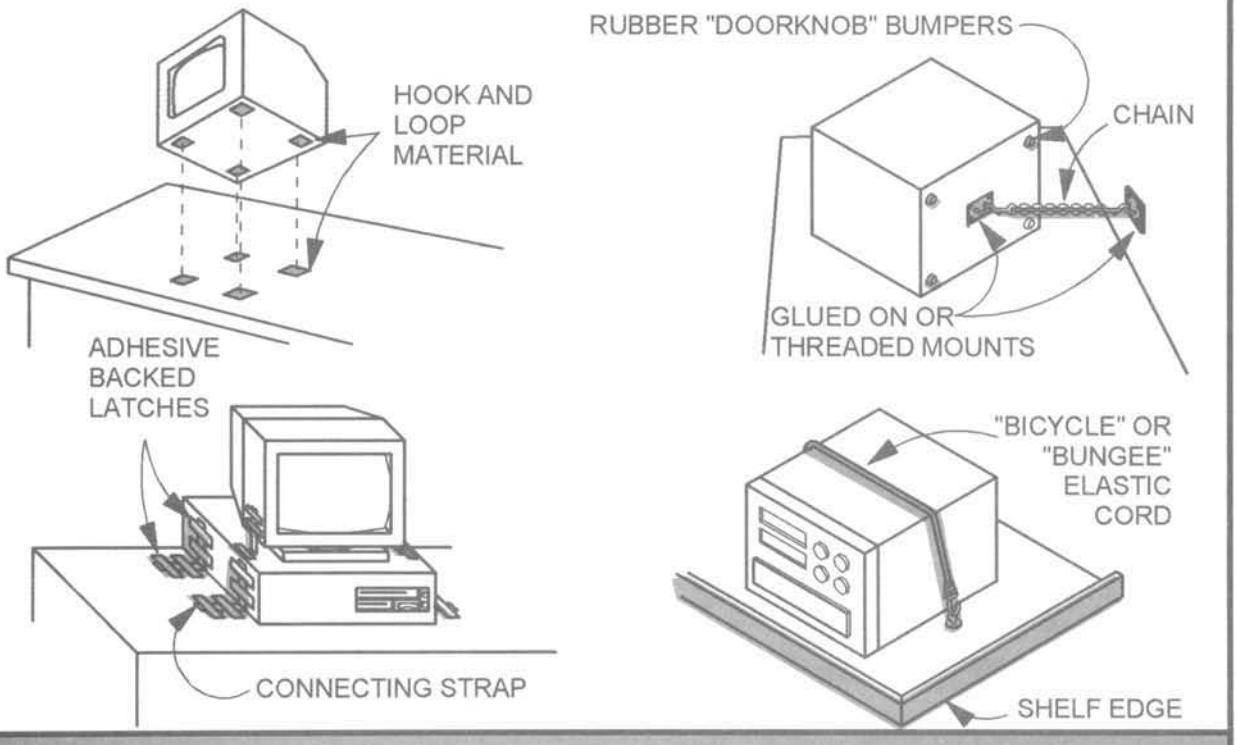
Schematic Upgrade Detail C8
Approximate Cost: Access floor alone -- $3 - $7 per square foot
Cabinet restraint -- $300 - $500 per cabinet

C8

DESKTOP COMPUTERS AND OFFICE EQUIPMENT

DO-IT-YOURSELF

Unsecured computers may fall and suffer damage
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

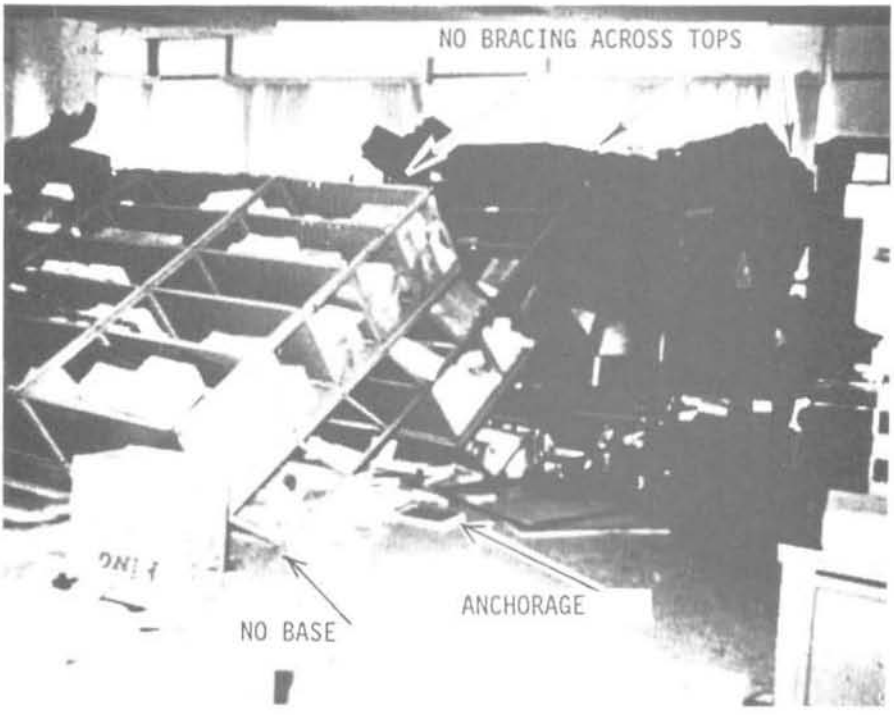


Upgrade Detail C10
Approximate Cost: $50 per computer

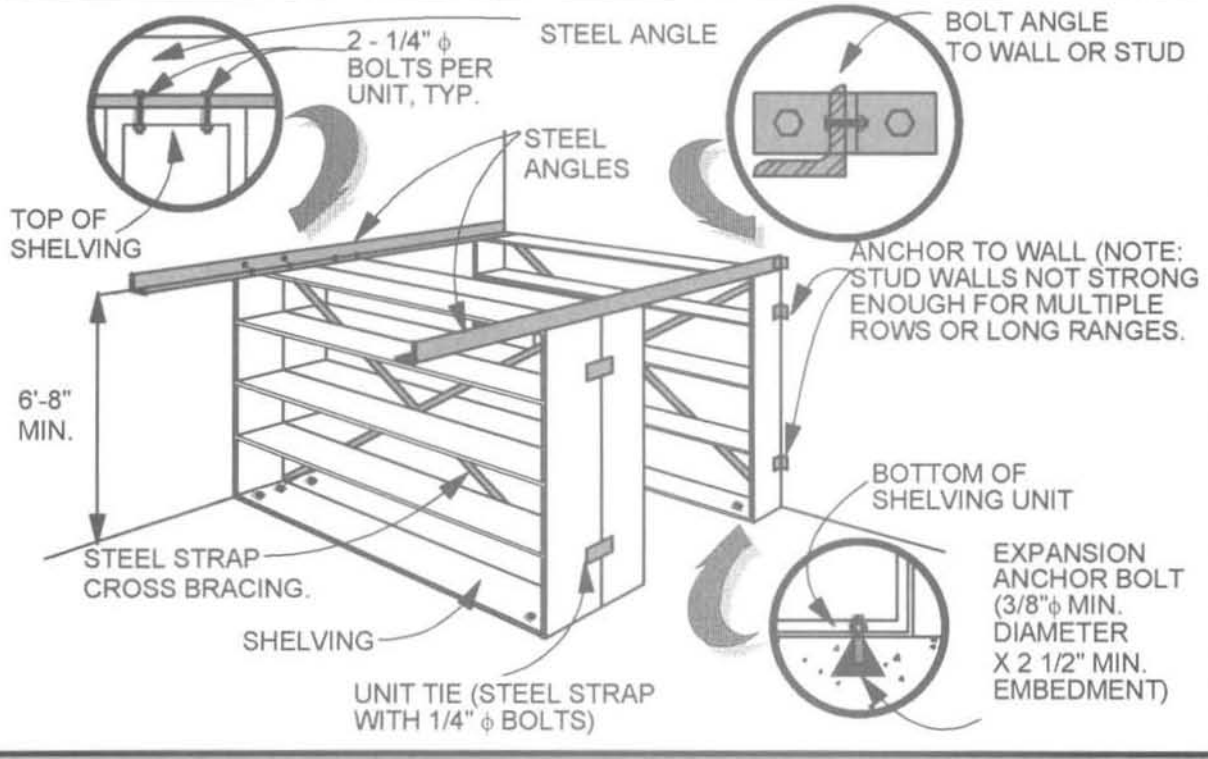
C10

TALL SHELVING: FREESTANDING

ENGINEERING REQUIRED



Earthquake Damage: 1972, Managua, Nicaragua
Photo Credit: John F. Meehan

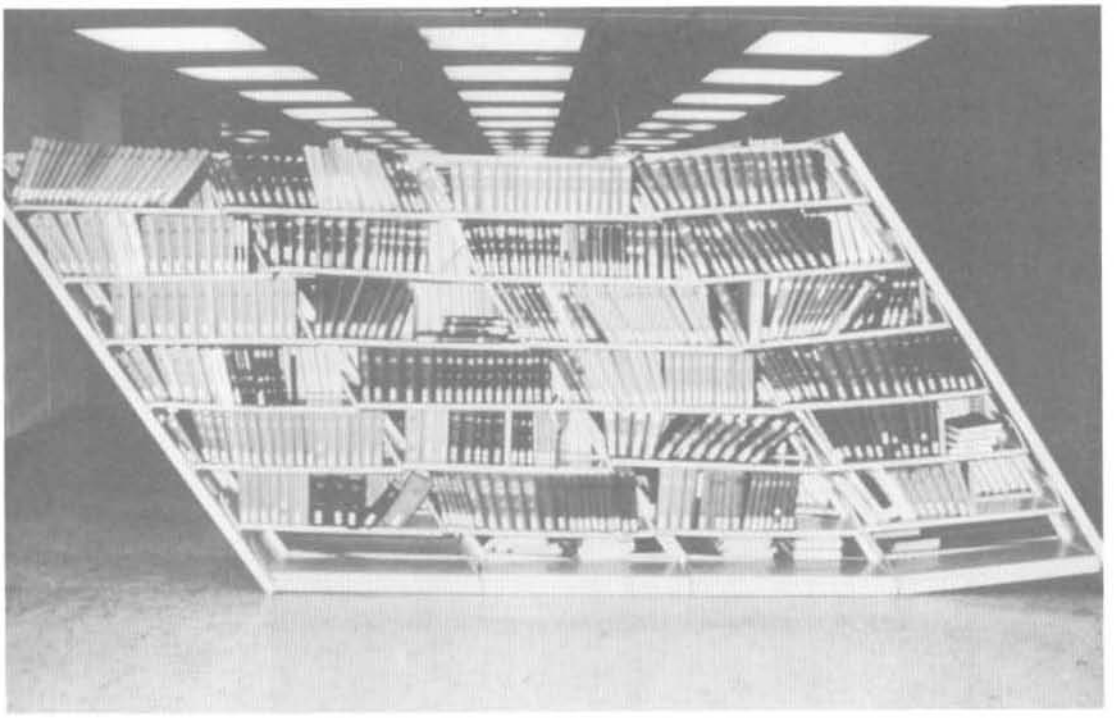


Schematic Upgrade Detail C12a
Approximate Cost: $20 per lineal foot of shelving

C12a

LIBRARY STACKS

ENGINEERING REQUIRED

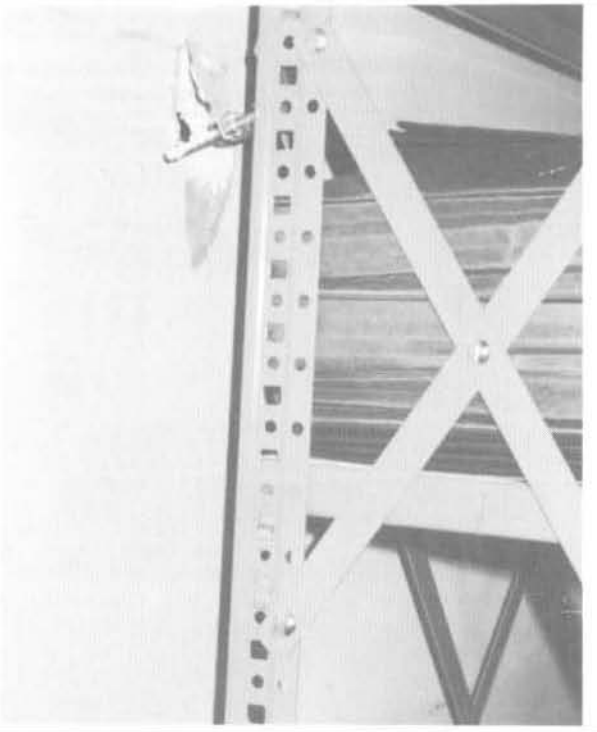


Failure of library shelving
Earthquake Damage: 1987, Whittier Narrows, California
Photo Credit: Earthquake Engineering Research Institute, Larry Parsons

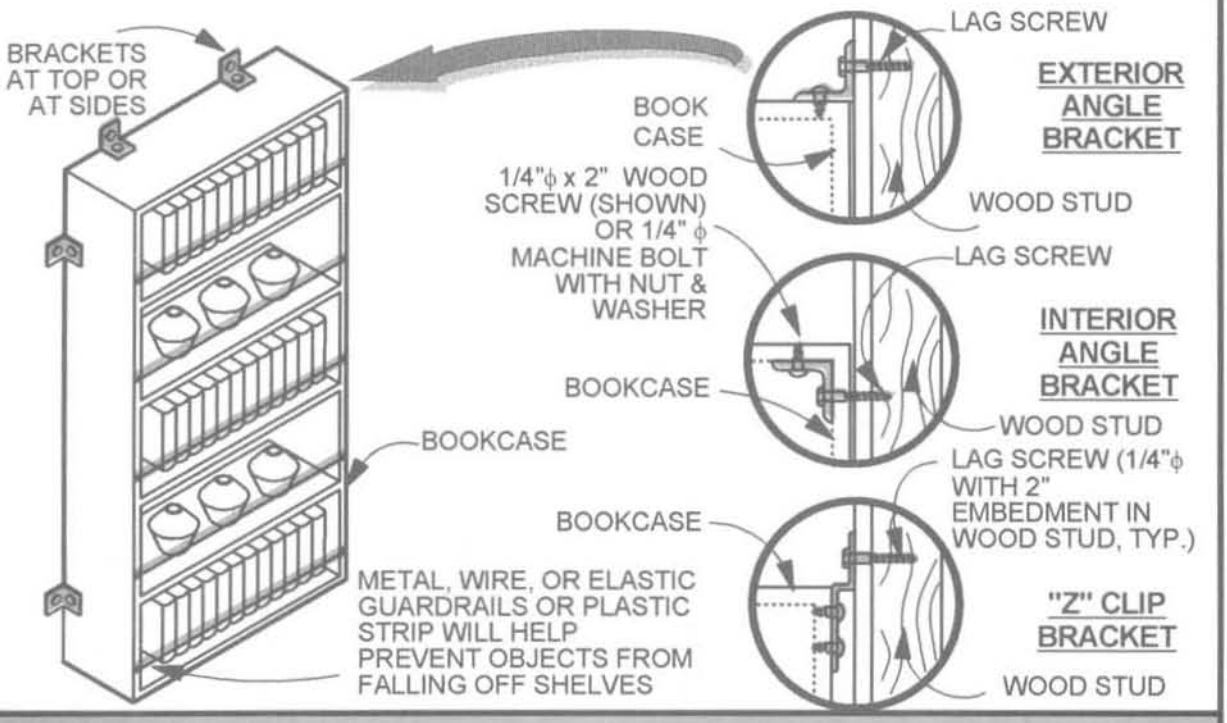
Failure of inadequately upgraded library shelving
Earthquake Damage: 1987, Whittier Narrows, California
Photo Credit: Earthquake Engineering Research Institute, Marshall Lew & Greg Brandow **C12b**

TALL SHELVING: WALL UNIT

DO-IT-YOURSELF



Failure of inadequately upgraded shelving; toggle bolt pulled out of gypsum board.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



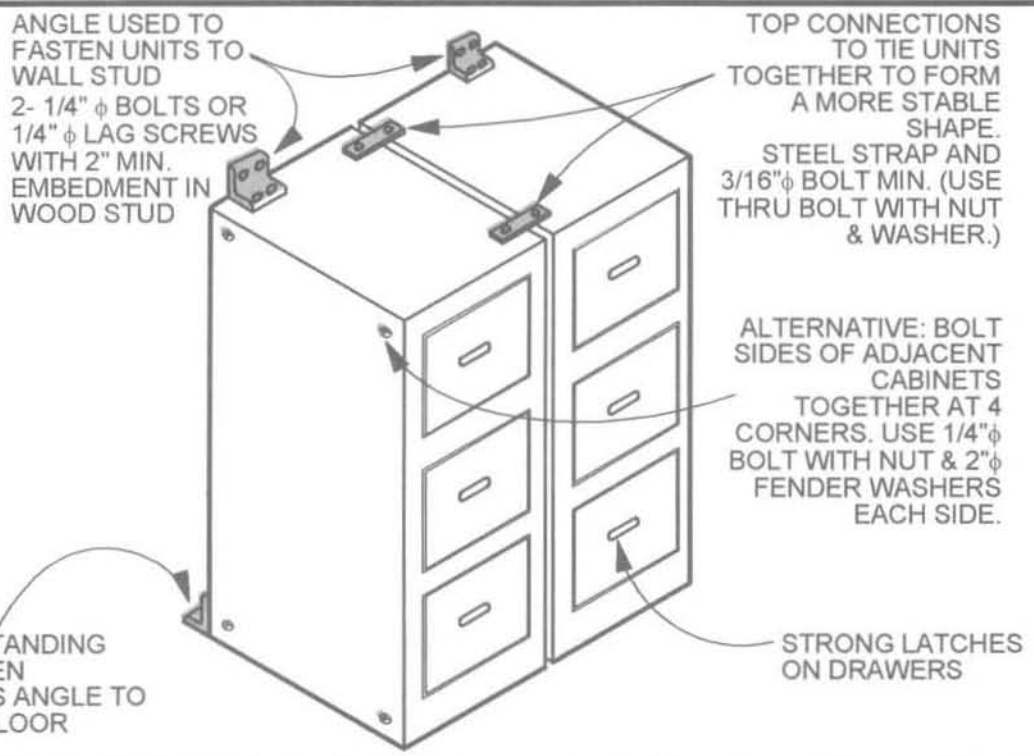
Upgrade Detail C12c
Approximate Cost: $20 per lineal foot of shelving

C12c

TALL FILE CABINETS

DO-IT-YOURSELF

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

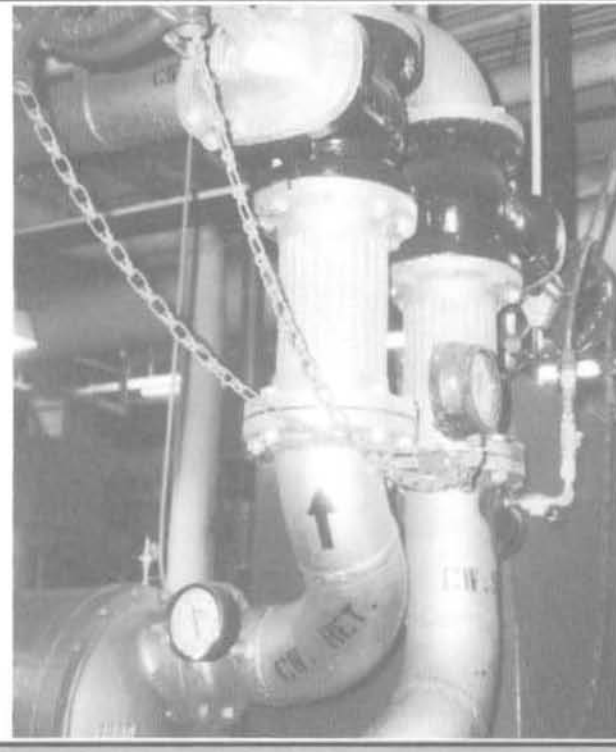


Upgrade Detail C13
Approximate Cost: $20 per lineal foot

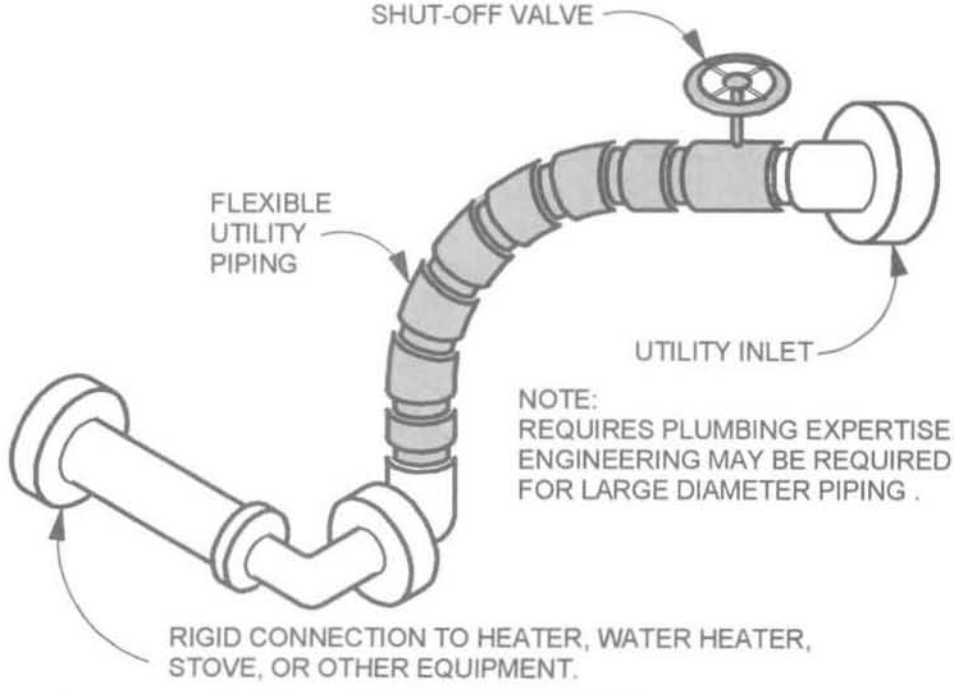
C13

FLEXIBLE CONNECTION FOR GAS OR FUEL LINES

DO-IT-YOURSELF



Flexible connection at pipe attachment to tank
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Upgrade Detail C18

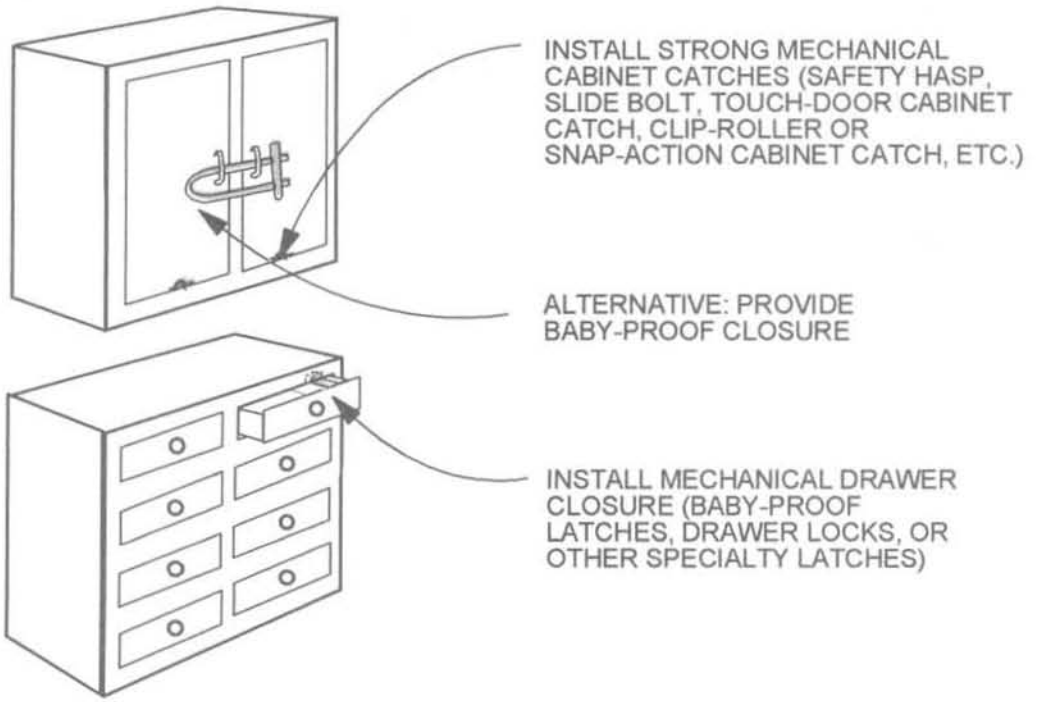
Approximate Cost: $100 for residential appliance; varies for larger items

C18

DRAWER AND CABINET LATCHES

DO-IT-YOURSELF

Unrestrained drawers and cabinets
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



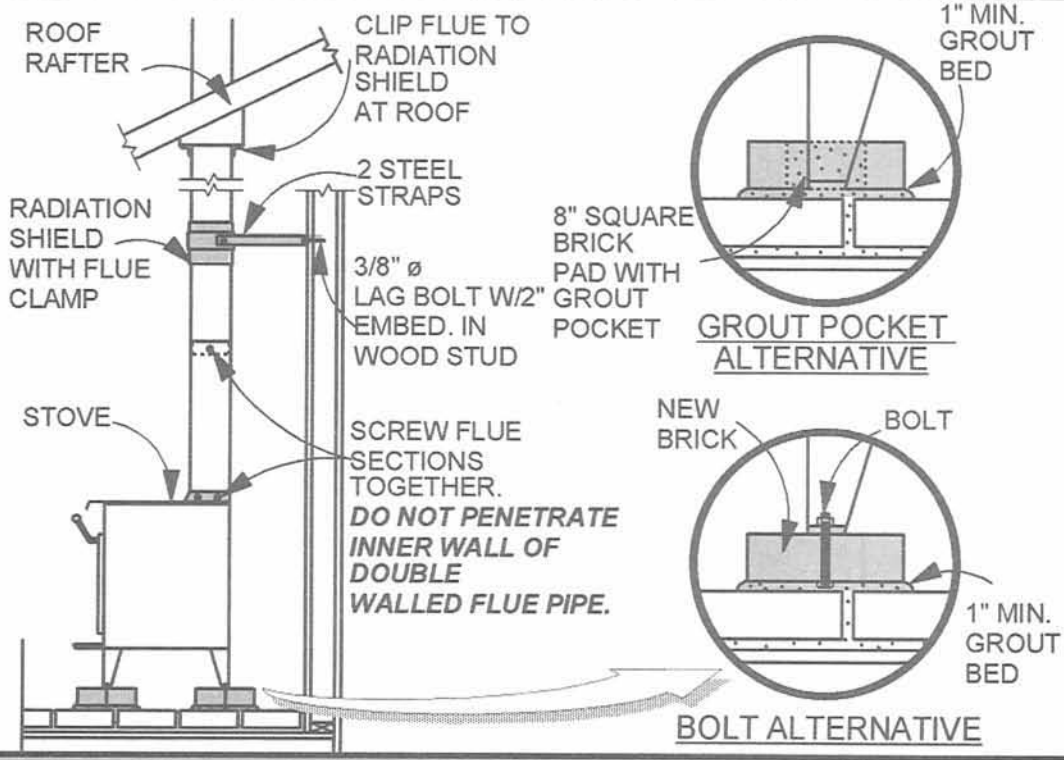
Upgrade Detail C19
Approximate Cost: $50 per cabinet

C19

FREESTANDING WOOD STOVE

DO-IT-YOURSELF

Unrestrained wood burning stove
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

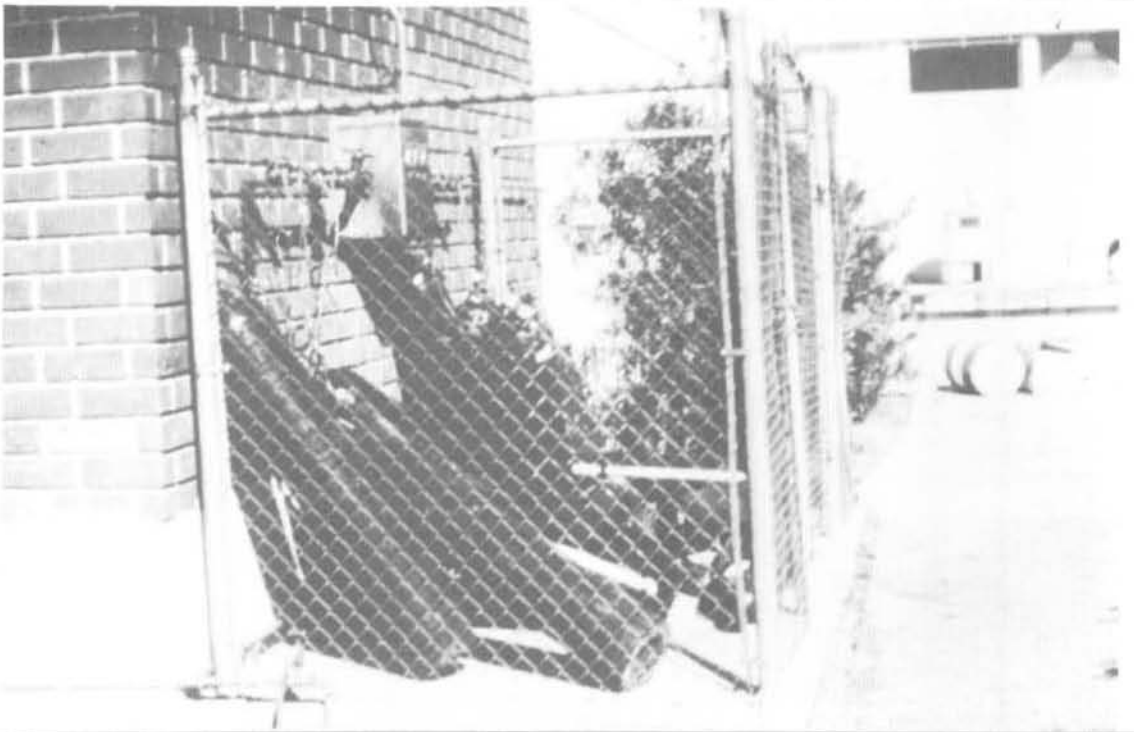


Upgrade Detail C20
Approximate Cost: $500

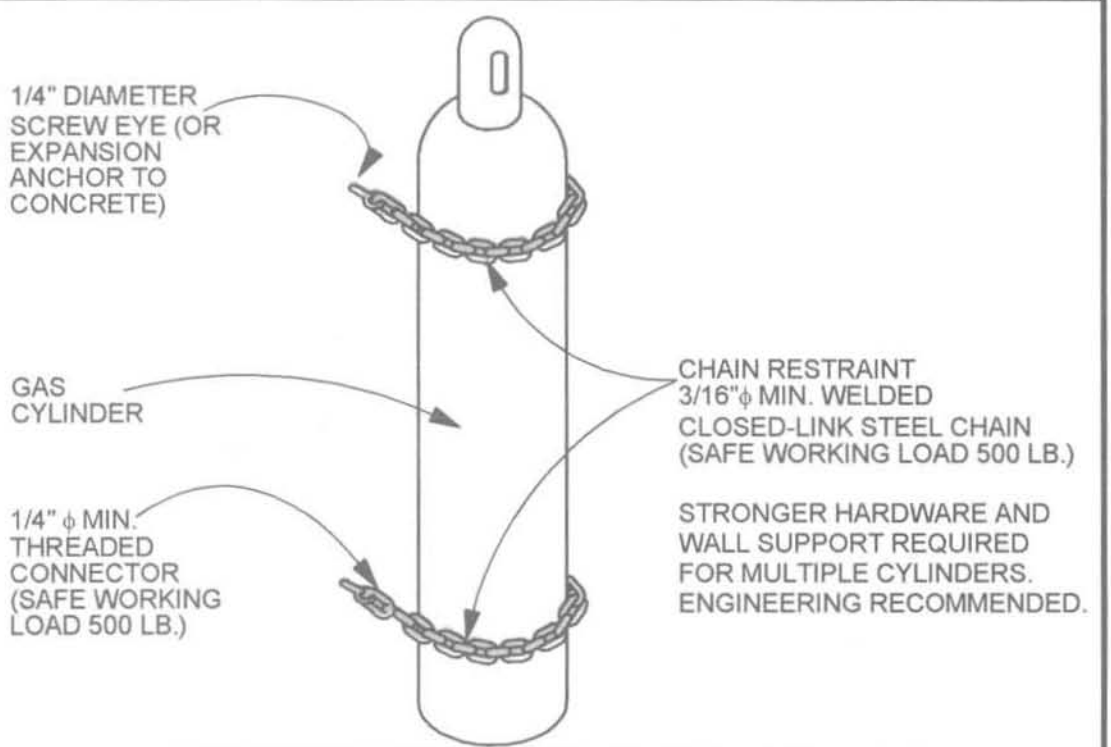
C20

COMPRESSED-GAS CYLINDERS

DO-IT-YOURSELF



Earthquake Damage: 1971, San Fernando, California
Photo Credit: Scientific Service, Inc.



Upgrade Detail C21

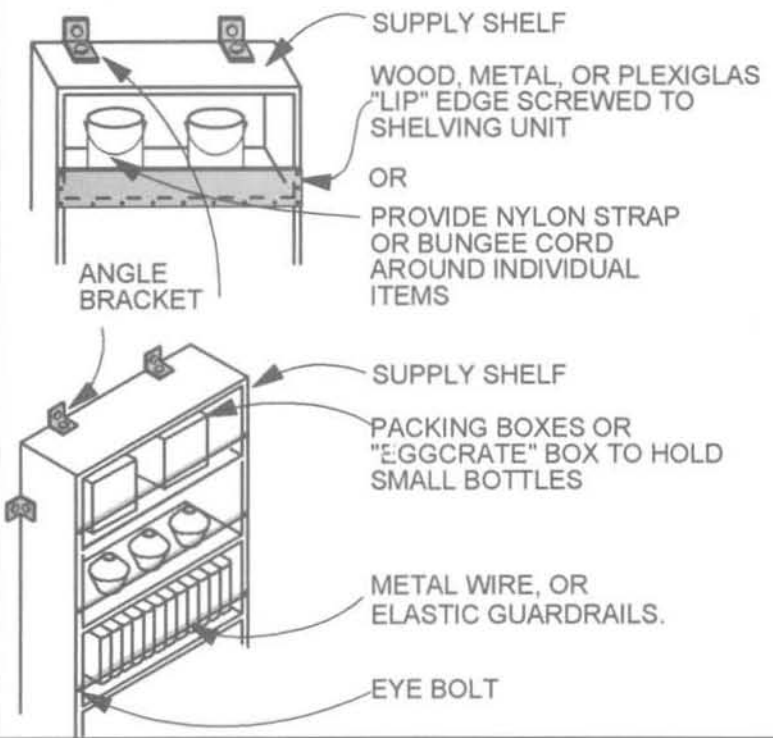
Approximate Cost: $30 per lineal foot; $50 for single units

C21

CONTAINERS OF HAZARDOUS MATERIALS

ENGINEERING REQUIRED

Spilled pharmaceutical and medical supplies.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Robert Reitherman



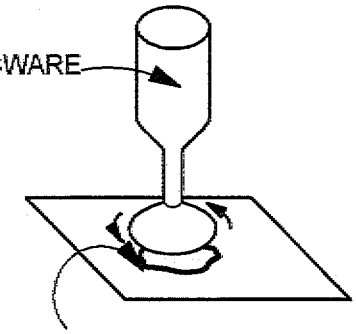
- ANCHOR STORAGE SHELVES
- PROVIDE SAFETY LIP OR SHELF EDGE
- PROVIDE MECHANICAL LATCHES FOR CABINETS AND DRAWERS
- STORE SMALL OR BREAKABLE ITEMS IN ORIGINAL PACKING OR EGGCRATE BOXES, NOT LOOSE ON SHELF OR IN DRAWER
- STORE INCOMPATIBLE MATERIALS AT A SAFE DISTANCE TO AVOID MIXING IF THE CONTAINERS FALL
- ORDER HAZARDOUS LAB CHEMICALS IN UNBREAKABLE PLASTIC BOTTLES OR IN GLASS BOTTLES WITH AN EXTERIOR PLASTIC SAFETY COATING

Schematic Upgrade Detail C22
Approximate Cost: Varies

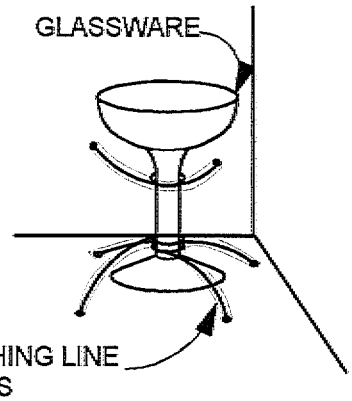
C22

FRAGILE ARTWORK

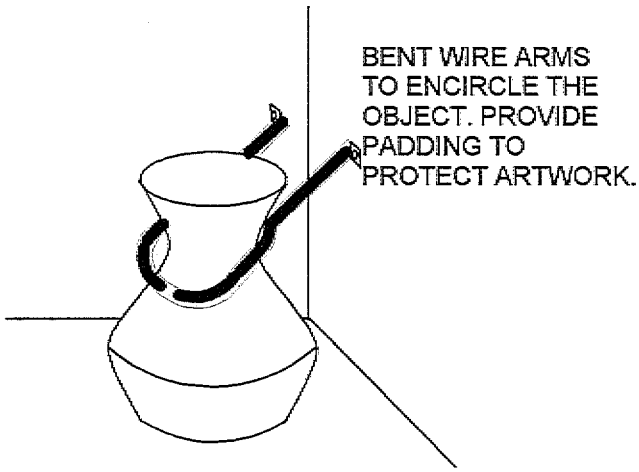
DO-IT-YOURSELF



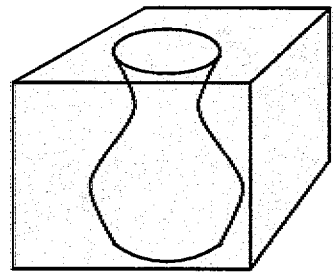
BEE'S WAX OR DENTAL WAX CAN RESTRAIN SMALL LIGHTWEIGHT OBJECTS. (REMOVE WITH CARE - WAX MAY LEAVE SMALL STAIN ON BASE OF OBJECT). ALTERNATIVE: USE PATCHES OF HOOK AND LOOP MATERIAL. [CAUTION – GLUE MAY AFFECT FINISH ON BASE OF OBJECT].



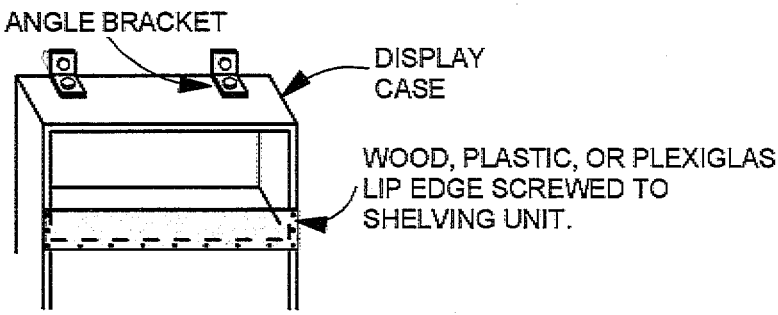
MONO-FILAMENT FISHING LINE USED FOR GUY WIRES



BENT WIRE ARMS TO ENCIRCLE THE OBJECT. PROVIDE PADDING TO PROTECT ARTWORK.



PLACE OBJECT IN CLOSE-FITTING GLASS OR PLEXIGLASS DISPLAY CASE. PEDESTAL MUST BE ANCHORED.



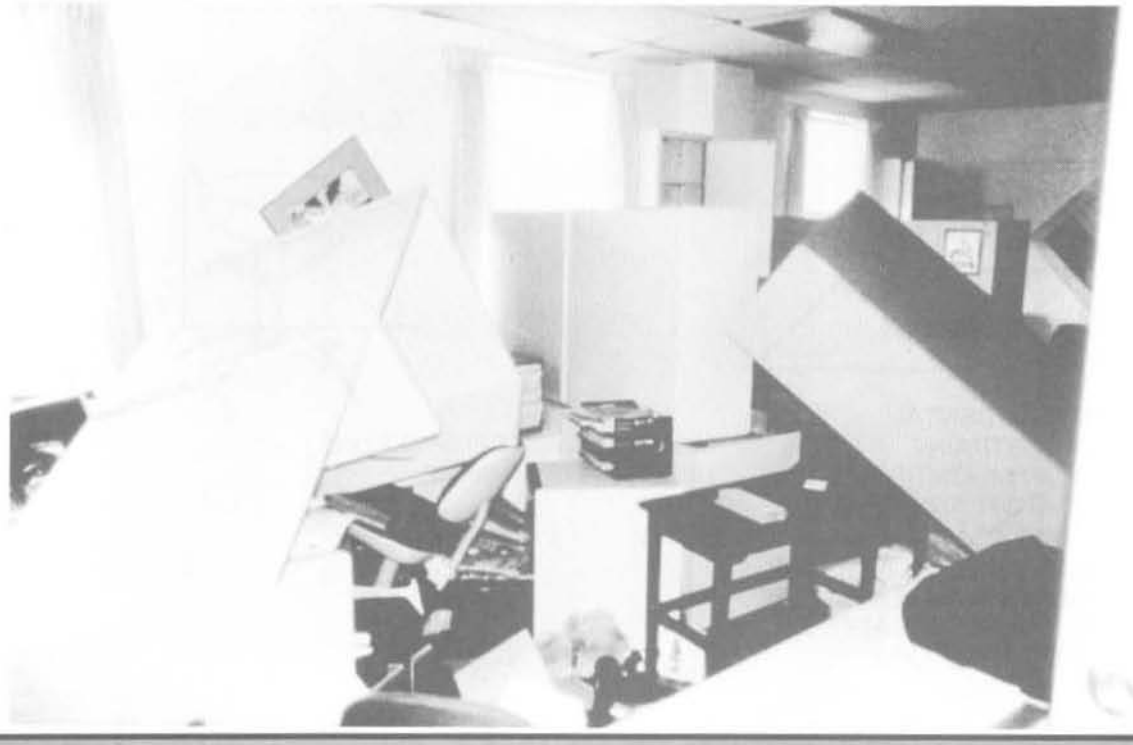
Upgrade Detail C26

Approximate Cost: Varies

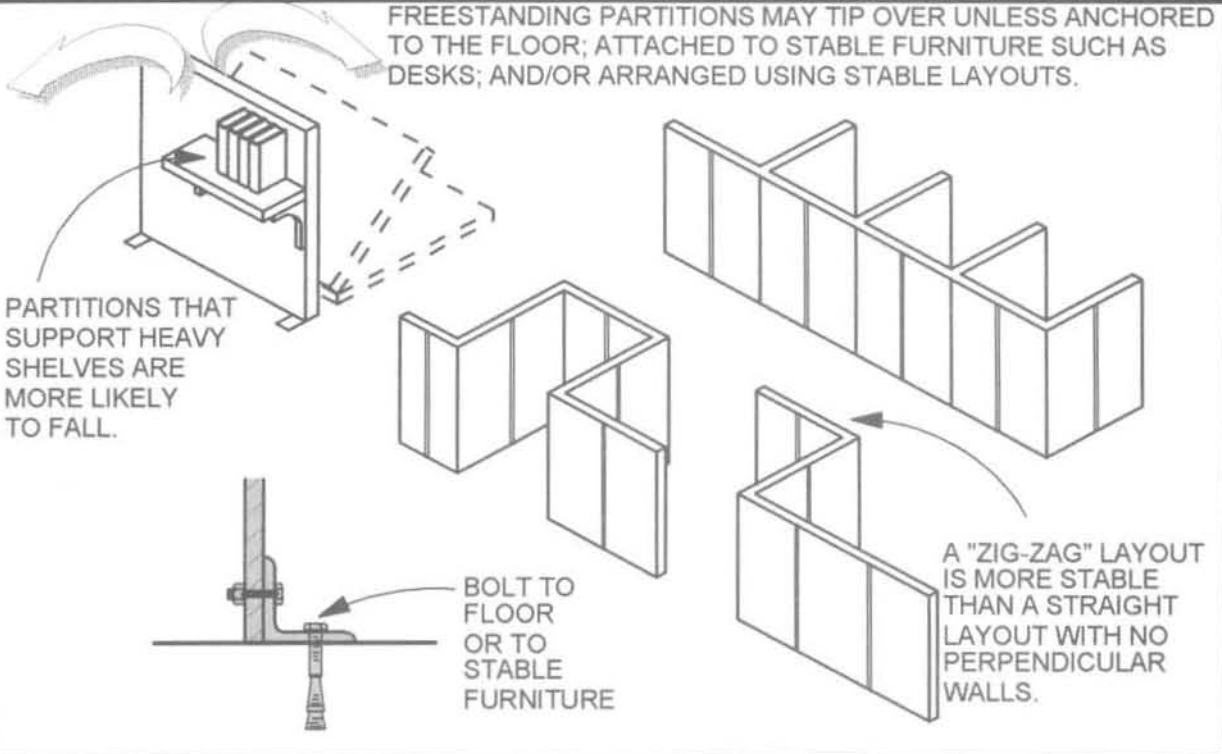
C26

FREESTANDING HALF-HEIGHT PARTITIONS

DO-IT-YOURSELF



Partition damage at Veterans Administration Medical Center in Sepulveda.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Earthquake Engineering Research Institute, James O. Malley



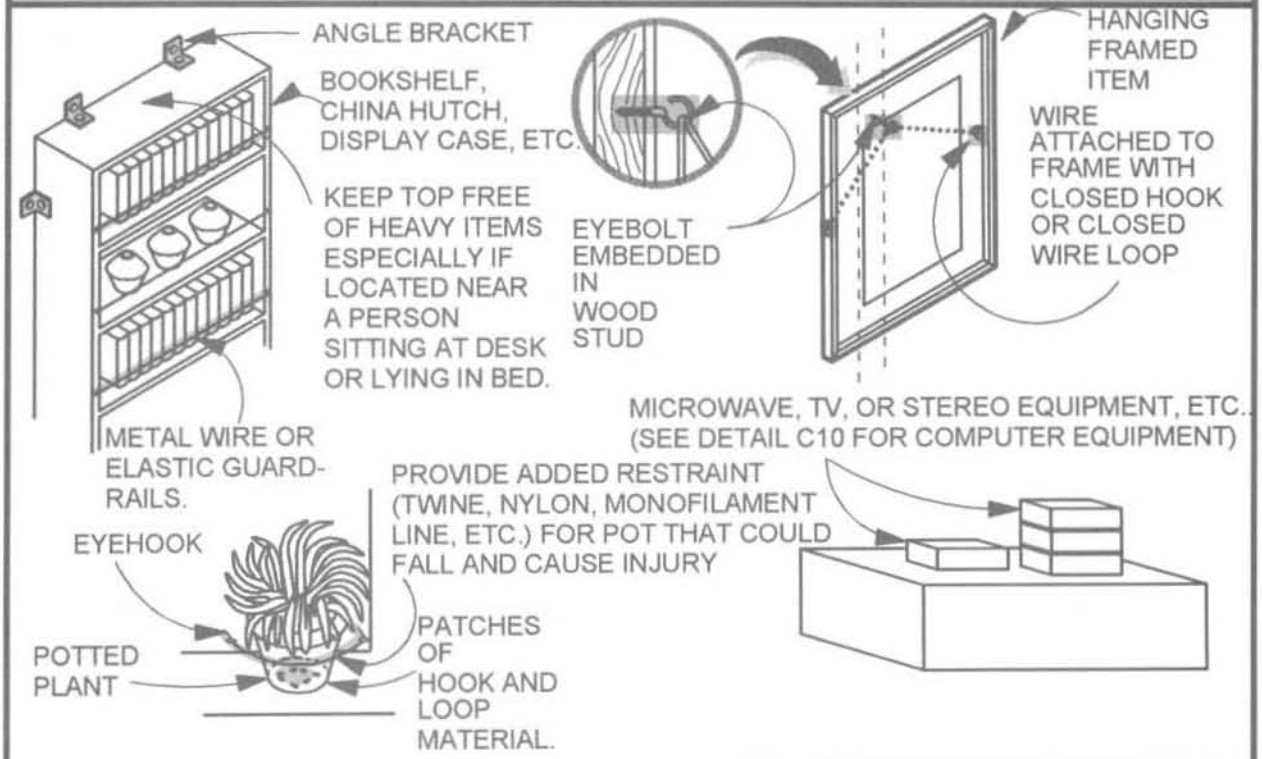
Upgrade Detail C27
Approximate Cost: $10 per lineal foot

C27

MISCELLANEOUS FURNITURE

DO-IT-YOURSELF

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Upgrade Detail C28
Approximate Cost: Varies, approximately $50 per item

C28

INSTALLATION NOTES

For those details where the self-help approach is acceptable, a few words of caution are in order. Many items shown in the upgrade details can be purchased at any hardware store, but it is important to select hardware that is appropriate for the task at hand. A toggle bolt mounted in gypsum board may hold a light picture frame on the wall, but is not appropriate for any of the details shown in this guide. At the other extreme, a 1-inch-diameter bolt is too large for a 2x4 wood stud, since the 1¼-inch-diameter hole you drill for the bolt will essentially eliminate the 1½-inch-wide stud. The following discussion provides general guidelines on hardware selection and installation procedures for the *Do-It-Yourself* details shown in this chapter.

Positive Connections The objective of nonstructural anchorage or restraint details is to provide what engineers refer to as a positive connection between the item and a hard attachment point, such as a solid wall, braced partition, concrete floor, or built-in countertop. Positive connections generally consist of some combination of screws, bolts, cables, chains, straps, steel angles, and other steel hardware. Positive connections do not rely on the frictional resistance produced by the effects of gravity. Neither the frictional resistance between the base of an object and the floor or other support nor such mechanical friction connections as C-clamps or thumbscrew clamps can be considered a positive connection.

The most common nonstructural connection details are for wall attachments, floor or ceiling attachments, countertop attachments for smaller items, and attachments between adjacent items to create a more stable configuration.

Typical Wall Attachment Details Many types of nonstructural items can be anchored, braced, or tethered to an adjacent wall to provide stability in an earthquake. Before installing any anchorage details, however, one should determine whether the wall has adequate structural capacity to support the nonstructural items. The wall element should consist of concrete, masonry, or structural framing members securely attached to the structural framing at both the top and bottom of the wall.

ANCHORAGE TO WOOD OR METAL STUD PARTITION WALLS

Any type of attachment hardware or brace should be attached directly to a structural stud, not to the gypsum board or plaster wall covering. Gypsum board and most other interior wall coverings have little capacity to resist out-of-plane loading, that is, loads perpendicular to the wall. Most likely, a toggle bolt or nail will simply pull out during an earthquake, leaving a hole in the wall.

Typical wood and metal stud walls are constructed with vertical studs located at either 16 inches or 24 inches on centers. Many interior partition walls extend only to the ceiling line and should not be used to anchor heavy nonstructural items unless the top of the partition wall is braced to the structure above. Heavy items anchored to unbraced partitions may bring the partitions down with them if they fall during an earthquake. Partition bracing should consist of diagonal elements of similar size and material as the vertical studs, spaced every few feet, connecting the top of the partition to the structure above. Engineering advice may be needed if the partitions appear questionable.

The structural studs should be located at the start of a project to see that they are within reach of the items to be anchored. In situations where many items must be anchored to a stud wall, it is sometimes advantageous to install a mounting strip first in order to avoid having to relocate items to line them up with studs. Sometimes referred to as seismic molding, a

mounting strip is a horizontal member mounted to the wall and anchored to each stud. The strip should be located at or near the top of the items to be anchored. Furniture or cabinets may then be anchored directly to the mounting strip without regard to the stud locations. A mounting strip may be constructed of a structural-grade wood 2x4 or 2x6 or a continuous steel channel or angle.

Recommended Hardware:

- Attach steel angle directly to wood studs using a minimum ¼-inch-diameter by 3-inch lag bolt. Embed the bolt at least 2 inches into the wood stud.
- Attach steel angle to metal studs using #12 sheet-metal screws long enough to penetrate the flange material. Use two screws per connection, located 3 inches apart vertically.
- Attachments to sheet-metal shelving or cabinets may be made by using a minimum ¼-inch-diameter machine bolt. Where possible, attach the bolt through two layers of material, for example where the top and side or back and side pieces overlap. Otherwise, use an oversized 2-inch-diameter by 3/32-inch-thick fender washer with the nut on the inside of the cabinet to provide additional strength.
- For seismic molding, use #14 flat-head wood screws with countersunk heads, with at least 2 inches embedded into the wood stud behind the wall covering. Locate screws along the centerline of the 2x4 or 2x6, and anchor the strip to each stud with maximum spacing of 24 inches on centers. For attachments to the molding strip, do not screw or bolt anything within 1 inch of each edge of a wood member.
- Small quick-release safety hooks (carabiners) and nylon cord or straps are often available at sporting-goods stores that carry mountain-climbing equipment. These items may be useful for tethering small office equipment.

Not Recommended:

- Toggle bolts mounted in gypsum board or plaster are not recommended for any of the details presented here.
- Nails have little capacity in tension or withdrawal, i.e., when you pull directly on the head of the nail. Thus, nails are not recommended for any of these details either.

ANCHORAGE TO CONCRETE OR MASONRY WALLS

Connections to existing concrete or grouted masonry walls should be made with concrete anchor bolts. Many types of anchors are available from various vendors, including expansion anchors, sleeve anchors, and epoxy anchors. Since the installation procedures and capacities for these anchors vary widely, it is important to check the local building code or vendor literature for the *allowable load* capacity and install the anchors in accordance with the manufacturer's recommendations. Holes into concrete or masonry walls should be drilled with care to avoid cutting any reinforcing steel (rebar). A magnetic device can be used to locate the steel prior to drilling. If rebar is encountered while drilling, stop, and relocate the hole; *do not cut through the rebar.*

The capacity of an anchor bolt in concrete is governed by the strength of the concrete, the bolt diameter, the depth of embedment of the bolt into the concrete, the spacing between adjacent bolts, and the distance to the edge of the concrete. In order to develop the full capacity of a concrete anchor, the spacing should be at least 12 diameters, with a minimum edge distance of 6 diameters. The minimum embedment length is typically 8 bolt diameters. The bolt will have a greatly reduced capacity if it is too near an edge or too close to an adjacent bolt or if it has insufficient embedment into the concrete.

The most common anchor bolts are wedge anchors, where part of the shank expands to press against the sides of the hole as the nut is tightened. Other types of anchors include sleeve anchors and epoxy anchors. Sleeve

anchors consist of a threaded sleeve installed directly into the concrete, flush with the concrete surface, and a bolt that is screwed into the sleeve. Sleeve anchors may be advantageous in situations where items may be moved frequently. The bolt may be removed, leaving the sleeve flush with the wall (or floor) and without leaving a protruding bolt. Epoxy anchors are inserted into slightly oversized holes with epoxy or polyester resin so that the adhesive will hold the bolt in place. Extreme care is required to ensure that the epoxy components are mixed in the proper proportions within the hole; otherwise the bolt will never reach the manufacturer's rated capacity. Quality control is critical for these bolts, and they are not recommended unless the installation is performed by experienced personnel.

Recommended Hardware and Procedures:

- Do not cut reinforcing steel or electrical conduit in concrete or masonry walls. Locate the steel or conduit with a magnetic device prior to drilling.
- Follow manufacturer's recommendations for installation. Remove dust from the hole prior to inserting the anchor bolt by using a hand-held vacuum cleaner; or blow the dust out with a bellows or a bulb.
- For anchorage to reinforced concrete walls, expansion anchors are the most common and easiest to install. Typical sizes for wall anchorage of nonstructural items might be a 3/8-inch-diameter A307 bolt with 3-inch minimum embedment (allowable seismic loads 1450 pounds shear and 650 pounds tension) or a ½-inch-diameter A307 bolt with 4-inch minimum embedment, 5-inch edge distance, and 6-inch spacing (allowable loads 2000 pounds shear and 1850 pounds tension) [12].
- To check the installation procedures and quality of workmanship, test a sample of installed bolts with a proof load.
- Use galvanized or preferably stainless steel bolts and other hardware in locations where they will be exposed to moisture or weathering.
- Corrosion-resistant chains, eyebolts, and quick-release safety hooks can often be found at marine supply stores. These fasteners may be needed to provide wall anchorage for gas cylinders or other items stored outside or in a damp location.
- For anchors in walls constructed of concrete masonry units, the expansion anchors should be installed only in grouted cells, i.e. locations where the cavity in the masonry unit is filled with grout and reinforcing steel. In order to achieve adequate embedment into the grout, longer bolts may have to be used in concrete masonry unit walls than in concrete walls. Unreinforced masonry walls, particularly cantilever partition walls, may not have adequate strength to anchor heavy nonstructural items. For light loads, up to 100 pounds or so, masonry toggle bolts can be used in ungrouted cells.
- For unreinforced brick walls, engineering assistance is recommended. Published capacities for expansion anchors typically apply to concrete, not to brick. Anchorage to the floor may be a preferable solution in a brick building.

Not Recommended:

- Adhesive or epoxy anchors are not recommended unless installed by experienced personnel. Proper quality control is critical for this type of anchor bolt.
- Inserts made of lead or plastic placed in holes drilled in concrete or masonry and used with lag screws have very limited capacity and are not recommended.

Typical Floor and Ceiling Attachment Details For heavy items, anchorage to a concrete floor slab is often preferable to wall anchorage because it avoids the additional seismic load to the wall. Ceiling attachment details are required for many types of piping, ducts, light fixtures, and overhead fans or heaters. The type of detail used in each situation will depend on the structural materials

of the floor and ceiling framing.

ANCHORAGE TO WOOD FRAMING

Because wood flooring typically does not have adequate strength to resist large concentrated forces, floor or ceiling anchorage hardware should be attached directly to the floor or ceiling beams or joists.

Recommended Hardware and Procedures:

- Locate the floor or ceiling joists prior to beginning work. If wood beams or joists are not situated within a convenient distance, wood blocking may be used to provide additional anchor locations. Install blocking perpendicular to the joists, using, as a minimum, a member of the same size as the joists. Anchor the blocking with framing clips to the joists at each end. Do not toenail the blocking.
- Wood screws or lag bolts should be used for simple anchorage connections for lighter items. A ¼-inch-diameter by 3-inch lag bolt will be adequate for many types of connections.
- For anchorage of heavier items to the roof or floor, add blocking beneath the anchor location, run A307 bolts through the blocking, and tighten them on the underside with nuts and washers.

Not Recommended:

- Do not anchor items directly to wood or plywood floor or roof sheathing, as these materials typically do not have adequate capacity to resist significant out-of-plane loads.
- Nails are not recommended for nonstructural anchorage details.

ANCHORAGE TO STEEL FRAMING

Caution should be used in anchoring nonstructural items to structural steel framing. Engineering expertise may be needed to determine whether holes can be drilled through structural steel framing without compromising the integrity of the structural members.

There are several types of connection details that do not require holes through the steel framing.

Recommended Hardware:

- Vendor catalogues of hardware that can be used to provide both vertical and lateral support for piping often include fittings specifically designed for steel framing. While C-clamps are not recommended, there are a variety of other devices that clamp mechanically around the flange of a steel beam or are designed to fit between column flanges. These devices are typically load-rated by the vendors and come in a variety of sizes. Besides bracing piping, this type of hardware might be used for bracing or anchoring items like lights or ceiling fans.

ANCHORAGE TO CONCRETE FLOOR OR ROOF SLABS

Concrete expansion anchors are the most common type of hardware used to anchor items to a concrete slab on grade or a structural floor slab. For heavy loads or concrete slabs less than 4-inches thick, it may be preferable to use through-bolts, i.e., machine bolts that go through the concrete slab and are fastened with nuts and steel plate washers on the underside of the slab.

Recommended Hardware and Procedures:

- Refer to discussion of expansion anchors under concrete wall anchorage details.
- *Do not cut reinforcing steel in concrete slabs or beams.* Locate the reinforcing steel and electrical conduit with a magnetic device prior to drilling holes in concrete slabs.
- For anchorage to a concrete foundation pad, slab on grade, or suspended floor, check the drawings for the thickness of the concrete, or drill a small pilot hole first. While short expansion bolts may be adequate to prevent sliding of low equipment, longer bolts with greater embedment are generally needed to prevent the combination of sliding and overturning forces for items that are taller than they are wide.

- Typical hardware for floor anchorage of lighter nonstructural items might be with a ½-inch-diameter A307 bolt with 4-inch minimum embedment and 6-inch spacing (allowable loads 1500 pounds shear and 1400 pounds tension). For heavy items, larger bolts are needed. For example, a 1-inch-diameter A307 bolt with 7-inch minimum embedment and 12-inch spacing (allowable loads 3750 pounds shear and 2850 pounds tension) [12]. Engineering assistance is recommended for very heavy items.
- If equipment is resting on leveling bolts or must be level for proper operation, vertically slotted connections may be needed to allow for adjustment.

Not Recommended:

- A ¼-inch-diameter expansion anchor has an allowable capacity for seismic loading of 650 pounds shear and 250 pounds tension [12]. (Note that the capacities cited above are for pure shear or pure tension. Combinations of shear and tension must be considered simultaneously, resulting in reduced capacity. For example, if you pull on the bolt with 200 pounds of tension, it will have the capacity to resist only approximately 300 pounds of shear.) These bolts are generally too small for most equipment or for fully loaded file cabinets, unless a number of bolts are used in combination.

Typical Shelf or Countertop Attachment Details If important or essential contents are to be secured, the shelf or mounting surface should be secured prior to anchoring nonstructural items. While standard desks and office tables are unlikely to overturn, they may slide during an earthquake. Desktop computers and printers can be anchored to the desk by means of hook-and-loop tape or various types of security devices designed to prevent theft.

Recommended Hardware and Procedures:

- Unanchored desks or tables may slide and pull on the electrical cords of office equipment if the items are anchored to the tabletop. Electrical cords should have adequate slack to allow for movement of unanchored desks or tables.
- Loose shelves should be secured to their wall or shelf brackets. Wood shelves that rest on wall-mounted brackets may be secured to the brackets with ½-inch-long wood screws.
- Many types of vendor-supplied anchorage and security devices are available for computer equipment. These may also be adapted for other types of countertop equipment, such as medical or laboratory equipment. Heavy-duty hook-and-loop tape with adhesive backing may be purchased at most hardware and fabric stores and can readily be cut into patches or strips.
- Desktop computer equipment usually consists of several independent components. If items are stacked, make sure each component is anchored to the one beneath it and that the bottommost item is anchored to the desk. For tall configurations of items that do not have to be moved frequently, it may be more advantageous to tie an assembly of components together with nylon strap and then anchor the base to the desktop.
- For light and nonessential items on shelves or countertops, a 1- to 2-inch lip secured to the edge of the counter or shelf may be adequate to prevent miscellaneous items from falling off. In this case, individual items need not be anchored.

Purchasing In some instances, it is easier to install nonstructural anchorage details for newly purchased equipment than for existing equipment. Many items are available off the shelf or can be special-ordered with seismic detailing. Some file cabinets come with predrilled holes for floor anchorage and strong latches on the drawers. Battery racks, industrial storage racks, and computer access floors can

be ordered that meet seismic requirements specified in the building code. It is always useful to inquire about the availability of seismic details when purchasing new equipment.

Patching, Painting, and Corrosion Protection Most of the details shown here assume that the nonstructural item is situated in a dry, interior location. In these locations, some cosmetic patching and painting may be desirable, primarily for aesthetic reasons.

For basements, roofs, or other exterior locations, it is important to provide adequate protection from weathering and corrosion. If attachment details perforate a roof membrane, appropriate sealants or localized repair will be needed to avoid roof leakage. If expansion anchors or other steel hardware will be exposed to moist conditions or weathering, either stainless steel or galvanized hardware should be selected to avoid corrosion and deterioration. Many types of paints and coatings are available that will help to retard corrosion. Exterior earthquake protection devices may need periodic maintenance to avoid deterioration.

In cases where a chain, latch, or tether is installed and users must remove and replace some hardware whenever they need to use the item, it may be helpful to select a bright or distinctive paint color as a reminder that the chain or hook needs to be refastened.

Safety Precautions As with any type of construction work, there are safety precautions that must be followed while installing nonstructural attachment details. Employers and tradesmen must comply with numerous local, state, and federal safety regulations and follow guidelines established for specific trades or industries. The following is not comprehensive but is a brief list of safety precautions that merit emphasis in connection with the nonstructural attachment details shown here.

Recommended Procedures:

- The people doing the installation work should have adequate training and supervision. Office workers or volunteers may not have the necessary background.
- Electrical hazards are present around any equipment supplied with electrical power. It may be necessary to disconnect the power before starting work. Transformers are especially hazardous. Transformers, switchgear, and other electrical cabinets should be handled or opened only by qualified personnel.
- The installation of most nonstructural restraint details involves the use of power tools. Personnel should use safety goggles and other protection recommended by tool manufacturers, and all workplace safety standards should be followed.
- Many heavy pieces of furniture or equipment may have to be moved temporarily in order to install seismic restraint details. Unless proper lifting techniques are utilized, back injuries or other injuries may result [19].