

TOKYO INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

ATCE-II

ADVANCED TOPICS IN CIVIL ENGINEERING

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**Temporary Structures**

**Shoring, scaffolding, and  
underpinning**



# **ATCE-II**

## **ADVANCED TOPICS IN CIVIL ENGINEERING**

### **Lesson 4: Shoring, scaffolding, and underpinning**

#### **Overview**

Shoring and scaffolding are the most frequent temporary structures in building construction. This lesson includes design, hardware, and installation of these systems. The last part of the lesson is underpinning, which is the installation of temporary or permanent support to an existing foundation to provide either additional depth or an increase in bearing capacity.

#### **Lesson Objectives**

By the end of this lesson you will be able to:

- explain shoring and how it is accomplished;
- describe scaffolding and its different types and application;
- describe underpinning, when it is needed, and how it is done.

#### **Reading Assignment**

M.K. Hurd, Chapter 4: 4-51-4-55 and Chapter 5: 5-3-5-7.

## Shoring

In multistory work, the shoring which supports freshly placed concrete is necessarily supported by lower floors which may not yet have attained their full strength, and which may not have been designed to carry loads as great as those imposed during construction. Construction loads may exceed design loads by an appreciable amount.

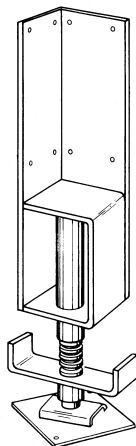
Therefore shoring must be provided for enough floors to develop the needed capacity to support the imposed loads without excessive stress or deflection. Whether permanent shores or reshores are used at the several required lower floor levels depends on job plans for reused of materials as well as the rate of strength gain in the structure.

There are several types of adjustable individual shores. The simplest of these, is based on clamping device which permits the overlapping of two 2×4 members.



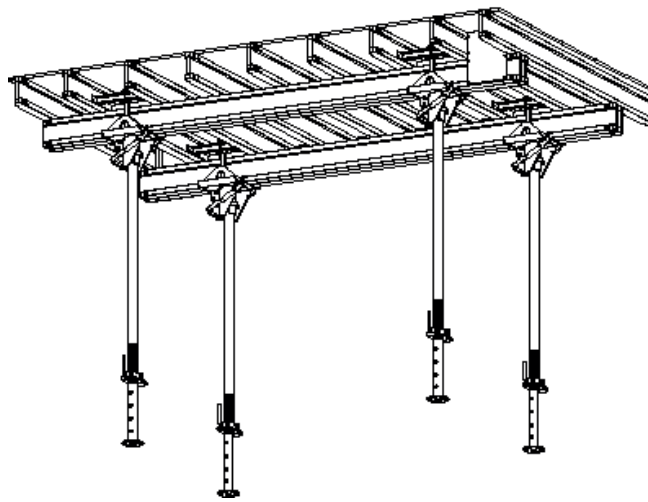
**Figure 1** - Using a clamping device, shores are made by joining two pieces of dimension lumber which also facilitates length adjustment

A portable jacking tool is used to make vertical adjustments. Metal shore jack fittings are available to fit over the end of 4×4 or 6×6 wood shore, thus transforming the piece of lumber into an adjustable shore, as shown in Figure 2. These devices are capable of varying the shore height as much as 12 inches.



**Figure 2** - Metal fitting are placed at the end of square lumber, making them adjustable shores

A number of patented shoring systems have been developed with adjustable legs which eliminate cutting, close fitting, and wedging. Figure 3 shows schematic diagram of one such device.



**Figure 3 - Shoring system with adjustable legs**

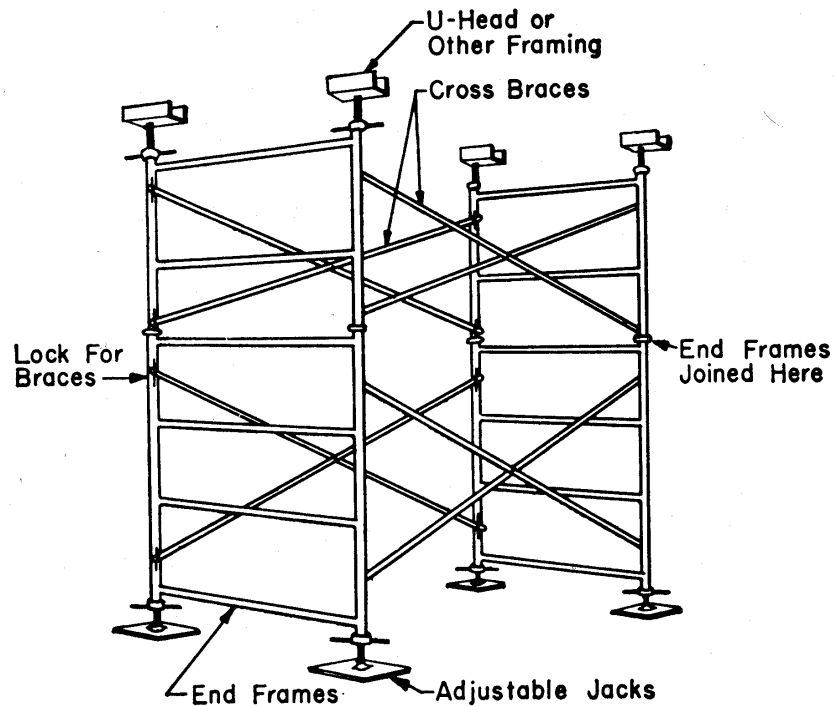
Figure 4 shows a picture where this device is being utilized.



**Figure 4 - Application of shoring system with adjustable legs**

### **Scaffold-Type Shoring**

Tubular steel form scaffolding was first designed to support loads imposed by the workers getting to the work area. Since the system of jacks in the tubular steel scaffolding makes it easy to adjust and level elevations, it is often used as a support for formwork. Since it is a modular assembly, it makes it an attractive option for rapid utilization for formwork support. A schematic diagram of a tubular steel scaffolding or shoring tower is shown in Figure 5.



**Figure 5** - A shoring tower is made by assembling end frames with diagonal braces

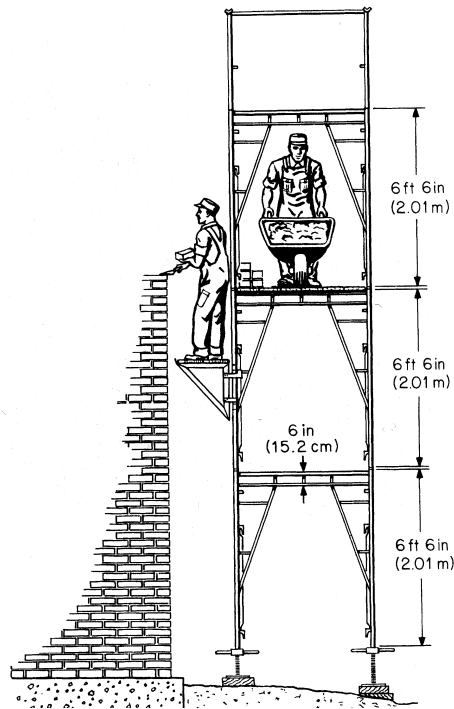
Figure 6 shows shoring towers being used in the construction of the new Computer Science building at the University of Washington campus.



**Figure 6** - application of shoring towers

### Scaffolding

Scaffolding has been used for many centuries to provide access areas for building and decorating structures taller than people who work on them (Figure 7).



**Figure 7 - Walk-through-type frames use by masons**

The word “scaffolding” refers to any raised platform or ramp used for ingress and egress for pedestrian movement and/or the passage of building materials. Since the mid-1920s the concept of using steel pipes fastened together with metal-form or cast clamps (couplers) instead of poles and ropes was introduced.

Aluminum alloy pipes and couplers were developed for their lighter weight and speedier construction. Aluminum alloy is only two-thirds as strong as steel, but it is only one-third to one-half its weight. Because of the higher initial cost, aluminum is restricted mostly to building maintenance scaffolds and suspended platforms.

### General Design Considerations

It is a common practice to use a minimum factor of safety of four in the design of all scaffoldings, meaning that scaffolds and their components can support four times the maximum design load without experiencing failure. For this reason, the design load is multiplied by a factor of 4, before determining limiting strength and yield stress of the metal used in the engineering design of scaffolds and their components.

### Design Loads

According to OSHA and ANSI criteria and many years of experience with these systems, design load ratings for scaffold platforms are as follows:

- **Light-Duty Loading.** 25 lb/ft<sup>2</sup> maximum working load for support of people and tools (no equipment or material storage on the platform).
- **Medium-Duty Loading.** 50 lb/ft<sup>2</sup> maximum working load for people and material often described as applying to bricklayers’ and plasterers’ work.
- **Heavy-Duty Loading.** 75 lb/ft<sup>2</sup> maximum working load for people and stored material often described as applying to stone masonry work.

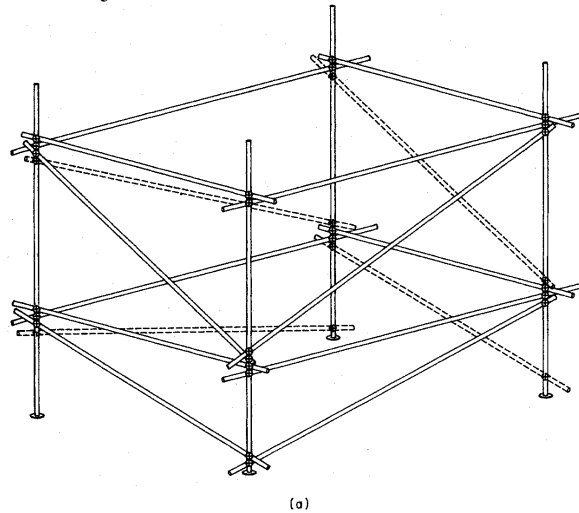
These ratings assume uniform load distribution. With the exception of the weight of stored materials, scaffold loads most often consist of personnel, both stationary and transitory. It is important to remember that the OSHA and ANSI load-rating system is intended for guidance of field personnel in the construction and use of nonspecifically engineered scaffolding applications.

### Tube and Coupler Scaffolds

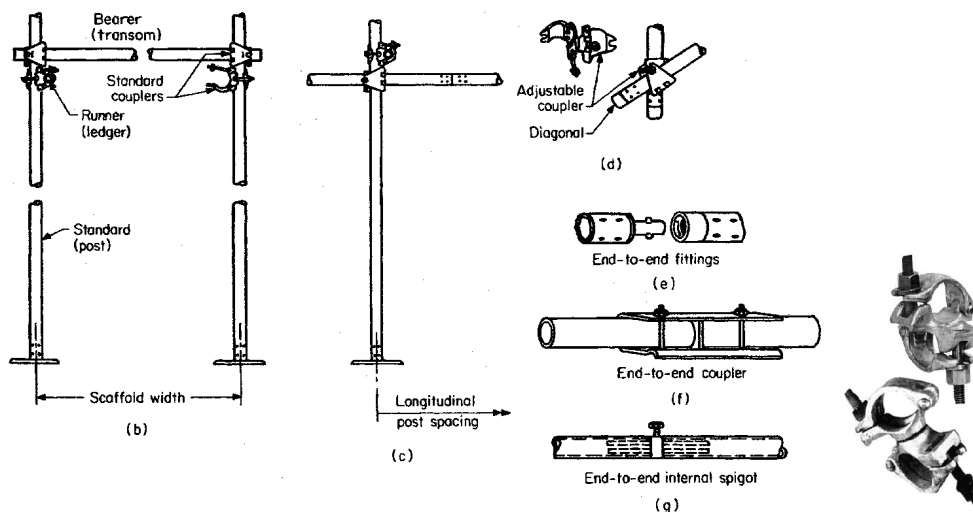
Tube and coupler scaffolds are assembled from three basic structural elements:

- the uprights, or posts, which rise from ground or other solid support
- the bearer, which supports the work platforms and / or provide transverse horizontal connections between the posts;
- the runners, which attach to the posts directly below the bearers and provide longitudinal connections along the length of the scaffold.

These three elements are usually connected with standard or fixed couplers which provide a 90° connection in two places and are shown in Figures 8a and 8b. Figure 8c shows the tube and coupler scaffold used on a job site.



**Figure 8a - The basic assembly of tube and coupler scaffolds**



**Figure 8b - The basic components of tube and coupler scaffolds**





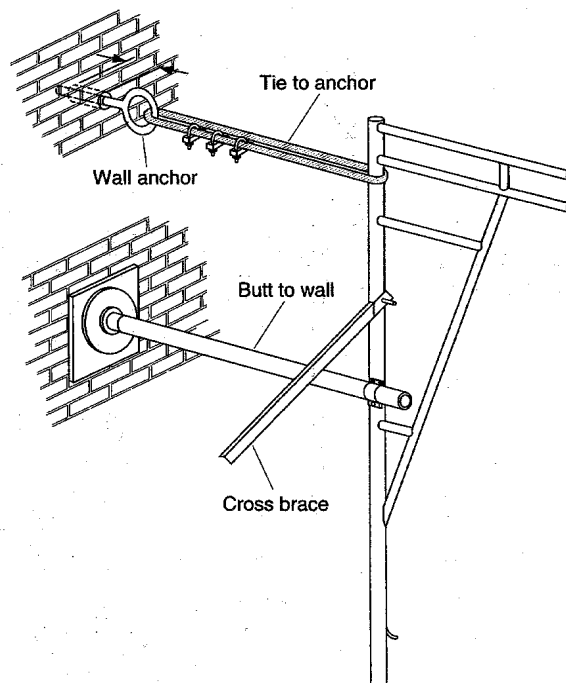
**Figure 8c** - Tube and coupler scaffolds used in the construction of the new Computer Science Building at the University of Washington

Diagonal bracing is used to stiffen the structure as necessary, most important in the longitudinal direction. Bracing is generally connected to the posts with “adjustable” or “swivel” couplers which have the facility of adjusting a full 360°. Diagonal bracing should always be attached to the posts as closely as practical to the “node” points formed by the runner-bearer connections.

Another important structural element is the building tie which connects the scaffold to the wall or structure and is needed to provide rigidity and anchorage of the scaffold in the transverse direction. Scaffolds need to be laterally supported; otherwise, they are unstable because of their height-to-width ratio and have low strength to resist wind and other lateral forces. Figures 9a through 9c below show a number of methods to provide anchorage of scaffolding to the structure.

### Methods of stabilizing against a building

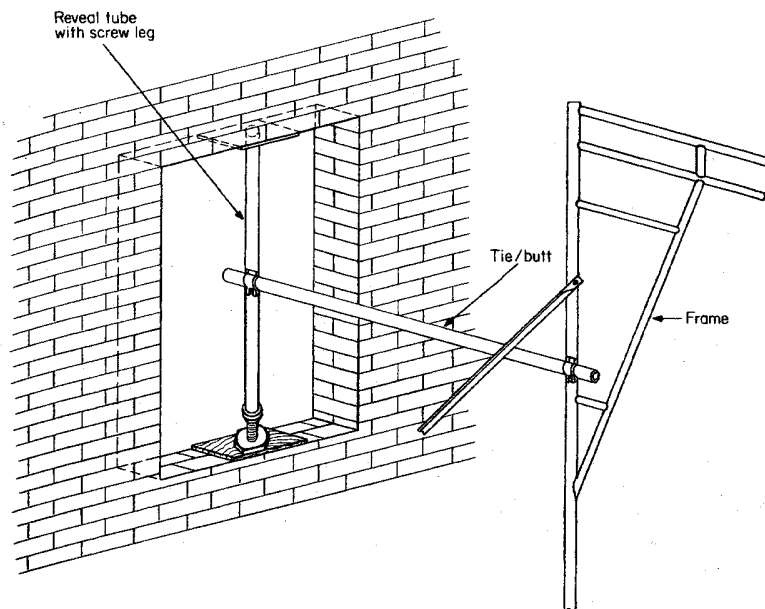
#### (a) Wall tie and anchorage



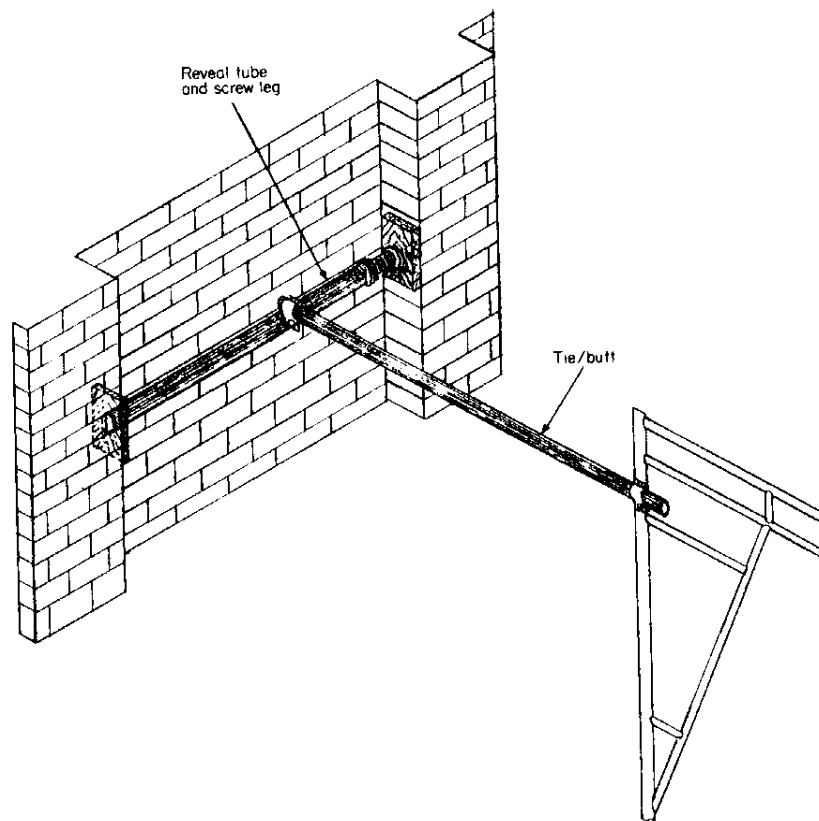
**Figure 9a** - Wall tie and anchorage



## (b) Window reveal tube

**Figure 9b - Window reveal tube**

## (c) Reveal between pilasters

**Figure 9c - Reveal between pilasters**

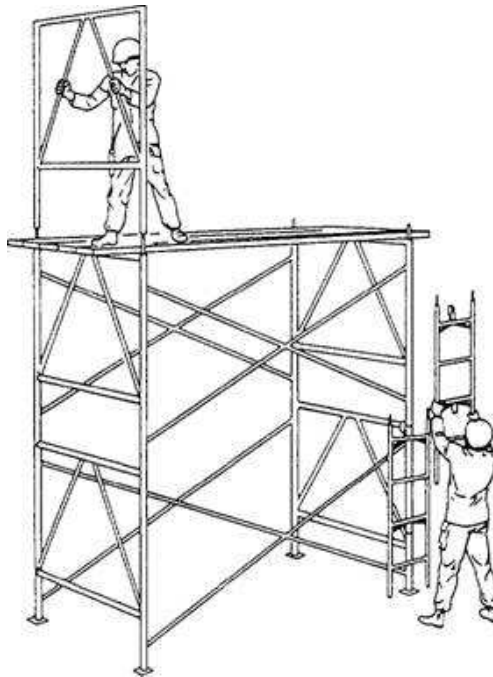
### Tube and Coupler Scaffolds: APPLICATION

Tube and coupler scaffolds can be assembled in many different ways because of the flexibility of their assembly dimensions in the horizontal and vertical planes. Tube and coupler scaffolds are more adaptable since they are not restricted by frame width in the transverse direction or by brace length in the longitudinal direction or by frame height in the vertical direction (unlike sectional frame scaffolds which is going to be discussed later in this lesson). Therefore for cases of irregular dimensions and contours, such as churches or old auditoriums, tube and coupler scaffolds become the preferred option since it makes access to the work place easier.

### Tube and Coupler Scaffolds: BASIC CONFIGURATIONS

The basic configurations are as follows:

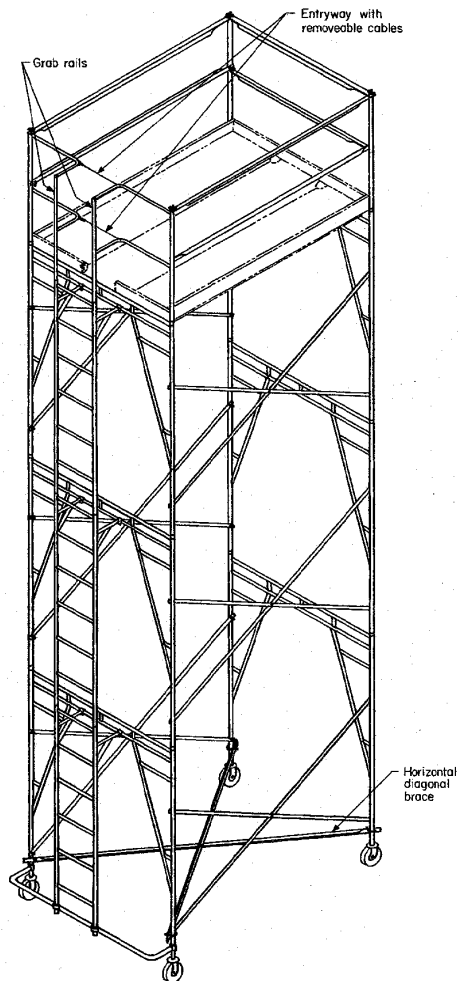
1. **Double Pole.** Double Pole or Independent Pole Scaffold is a scaffold supported from the base by a double row of uprights, independent of support from the walls and constructed of uprights, ledgers, horizontal platform bearers, and diagonal bracing (Figure 10a).



**Figure 10a** – Double or independent pole scaffold

2. **Single Pole.** Single Pole Scaffold is a platform resting on putlogs (putlog is a scaffold member upon which the platform rests) or crossbeams, the outside ends of which are supported on ledgers secured to a single row of posts or uprights and the inner ends of which are supported on or in a wall.
3. **Tower Scaffolds.** These consist of one or few bays in either horizontal plane, constructed to required height for access to ceilings or for specialized load support requirements not conveniently achievable with sectional frames. They may be mounted on casters and become mobile scaffolds or rolling towers, as shown in Figure 10b.

An application of tower scaffolds is to provide stair access to unusual structures such as cooling towers.

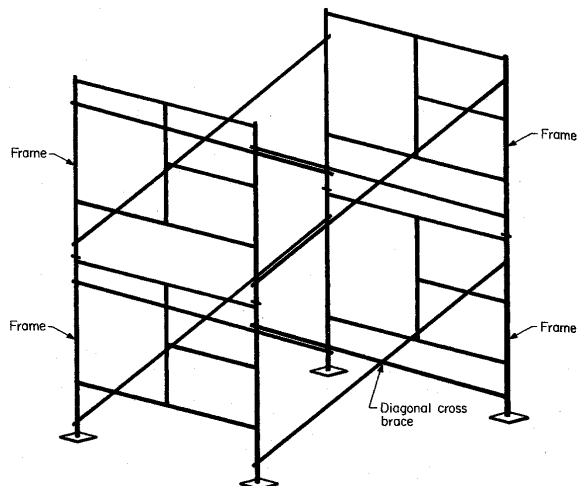


**Figure 10b** - Rolling scaffold with stand-off ladder

Generally, in the U.S. pipe is classified by its internal diameter (ID) and tubing by its outside diameter (OD). The most common pipe or tube used in tube and coupler scaffolds is 2-inch OD. For scaffolding purposes, tubing is manufactured to 1 29/32 inch OD (often referred to as 2-inch nominal OD pipe or tube) is designated as “pipe size” tubing.

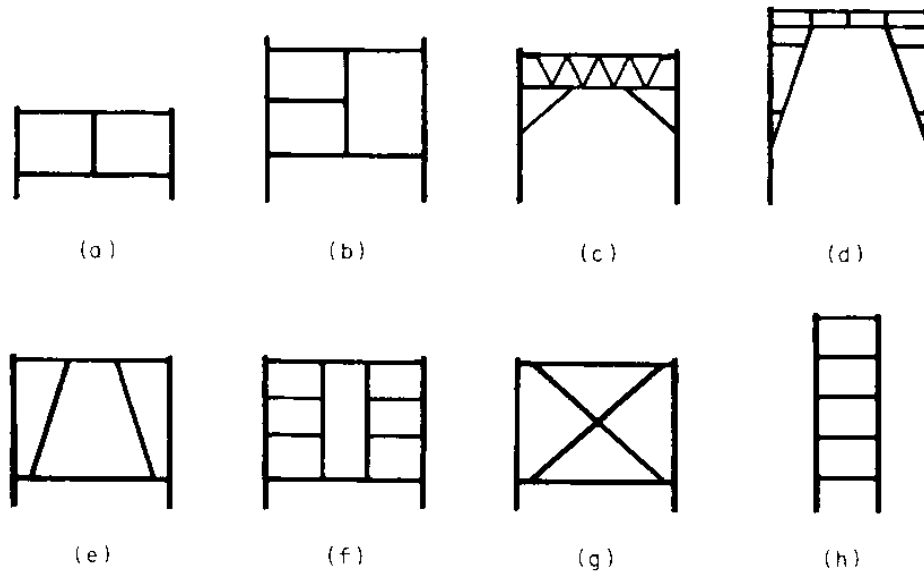
### Sectional Scaffolding

The construction principle of sectional scaffolding is shown in Figure 11.



**Figure 11** - Basic assembly of sectional scaffolding

Sectional scaffolding is available in many frame configurations. Most frames are available in the widths of 2, 3, and 5 feet. Some special purpose frames are available in 4 and 6 feet widths (6-ft frames are used in sidewalk canopies). Standard frame heights are 3, 4, 5, 6, and 6.5 feet high for sidewalk canopies. The frames are also available in heights of 7.5, 8, and 10 feet. Figure 12 shows some typical representative frame designs.



**Figure 12** – Representative designs of sectional scaffolding frames

The most common material used in the fabrication of steel frames is 1 5/8-in.- OD tubing with a wall thickness between 0.086 and 0.105 in. The most common grade of steel used for this purpose is AISI designation A1050, a high-carbon alloy having a minimum yield stress of 50,000 psi with a corresponding ultimate stress of over 75,000 psi. The higher carbon steel is generally preferred because its lower ductility and greater rigidity make it more resistant to damaging and bending of the members and because it has greater strength.

### Underpinning

Underpinning is the installation of temporary or permanent support to an existing foundation to provide either additional depth or an increase in bearing capacity. There are several existing conditions which may lead to the need for underpinning. They are

- Construction of a new project with a deeper foundation adjacent to an existing building
- Settlement of an existing structure
- Change in use of a structure
- Addition of a basement below an existing structure

Settlement of existing structures in many cases is caused by lowering of the water table due to tidal fluctuations, wells for a water district, etc. This lowering of the water table can cause the tops of timber piles to decay over time and will require remedial underpinning. With certain soil profiles, rising of the water table can effect a decrease in bearing capacity of the soil causing settlement and require underpinning.

Construction of structures on unsuitable bearing material or over compressible layer (peat, organic silts, or poorly compacted backfill) may cause settlement.

### Determining the need for underpinning

Underpinning is the direct support of an existing building foundation. It provides the opportunity to preload (i.e., jacking) to limit settlement and improve poor foundations. When a structure starts showing signs of settlement or distress, it is of utmost importance to precisely monitor the settlement or movement by a professional on a daily, weekly, or monthly basis, depending on the severity of the movements. Plotting these readings will indicate if the movements are decreasing or increasing, and by analyzing the results, a decision can be made whether or not underpinning (or other measures) are required to safeguard the structure.

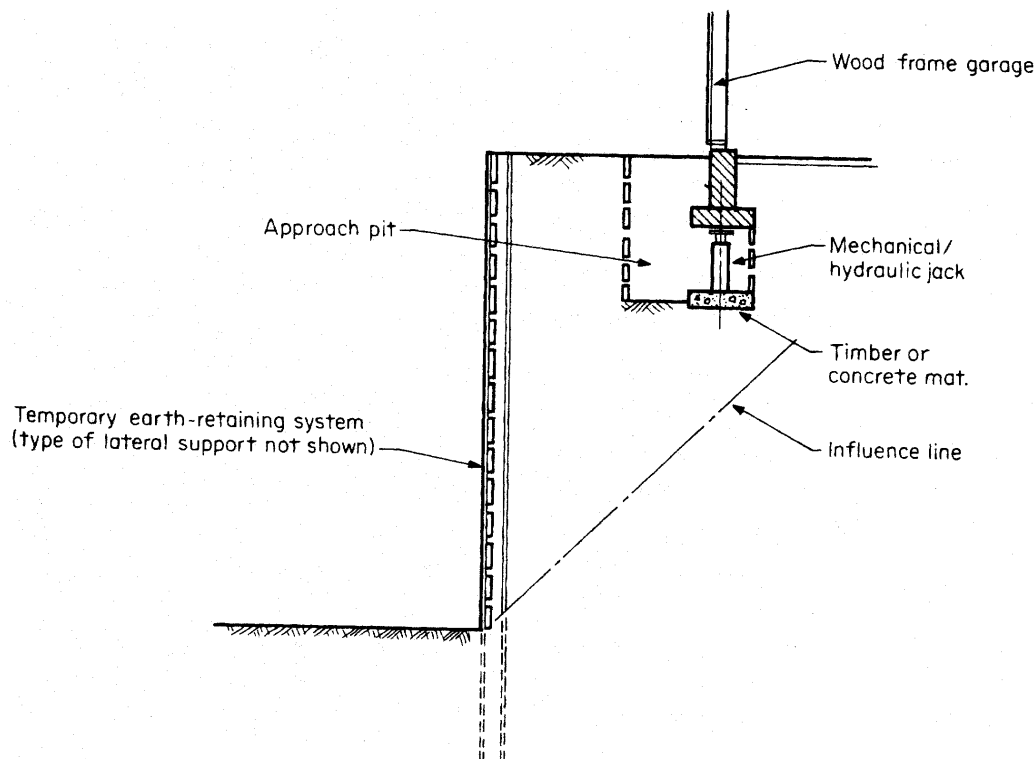
Prior to the start of excavation for a new structure, it is advisable to have a professional examine all structures in close proximity to the construction site, to determine whether or not underpinning is necessary.

### Underpinning Methods

#### Temporary support with Maintenance Jacking

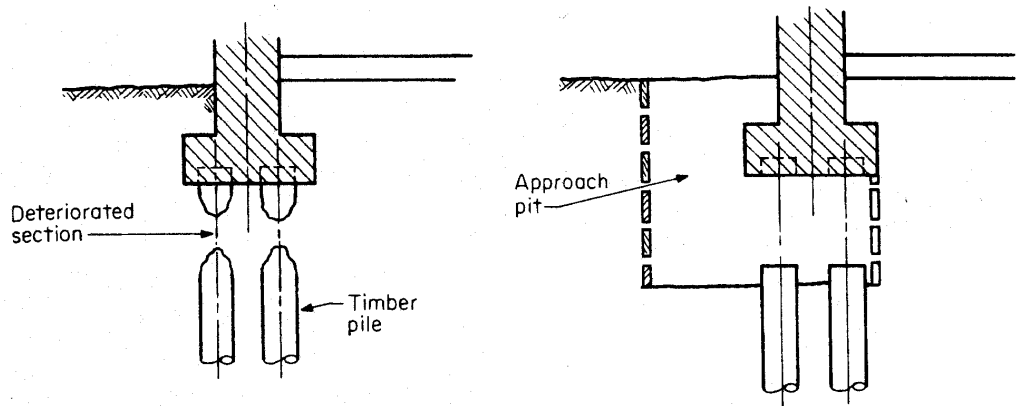
Light structures (for example, wood-frame garages) that fall within the influence line of the adjacent excavation and which do not warrant the expense of an underpinning installation may be supported on timber or concrete mats.

If settlement occurs, the structure will be kept at the same level by means of mechanical or hydraulic jacks, as shown in Figure 13.



**Figure 13 - Temporary support with maintenance jacking**

At completion of the work in the adjacent lot, the jacks are replaced with short steel columns, and the void is filled with concrete. Figures 14 shows the steps required for underpinning.

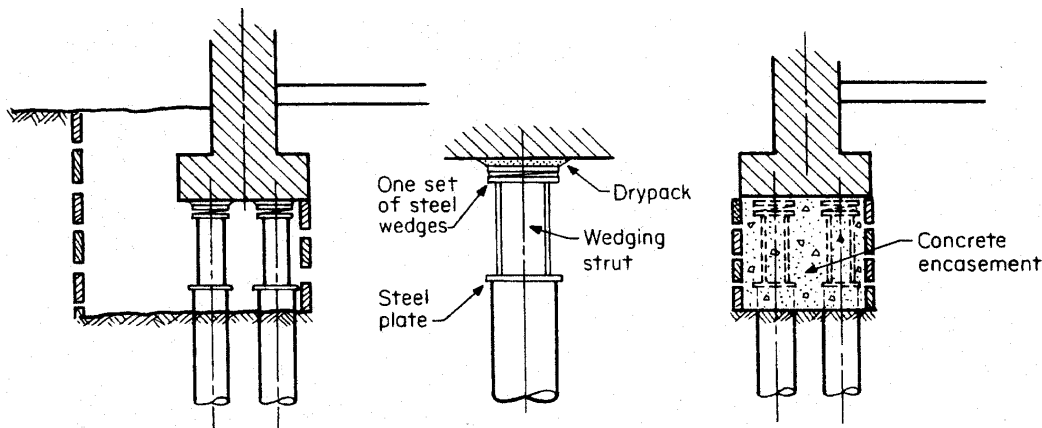


Existing foundation condition prior to underpinning

Step 1:

Shore existing construction, excavate approach pit, and expose existing timber piles.

Remove top portion of the piles and cut piles at new cut-off elevation.



Step 2:

Install steel plates, drypack, and wedging strut. Transfer load into pile by means of steel wedges.

Step 3:

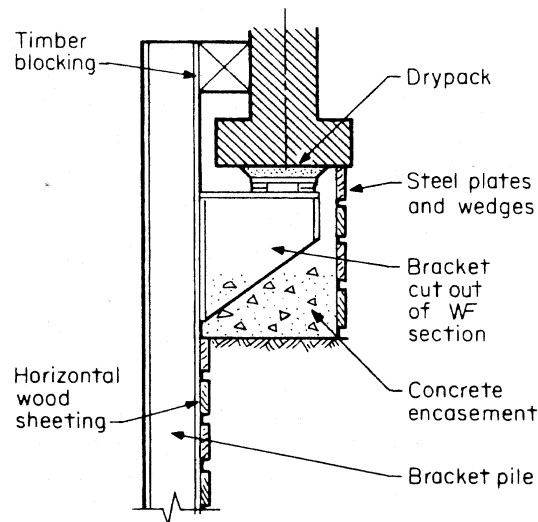
Placement of concrete encasement, backfill approach pit.

**Figure 14 - Underpinning timber-pile foundation**

**Underpinning Methods - Bracket Pile Underpinning**

When both the existing and future structures belong to the same owner, the use of bracket piles is very economical (most municipal building codes do not allow a building to be supported on the foundation that is located on someone else's property). The steel bracket piles are driven or placed adjacent to the future structure in pre-augured holes which are then backfilled with a lean sand-cement mix. The load is transferred from the structure into the pile through a steel bracket welded to the side of the pile. A combination of steel plates, wedges, and drypack is installed to ensure a tight fit between the structure and the bracket, as shown in Figure 15.





**Figure 15 - Bracket pile detail**

This type of underpinning can be utilized for structures up to two stories high, depending on the weight of the building and the quality of the bearing material at subgrade or the new structure. The spacing of the piles depends on the load distribution in the existing structure. The maximum spacing should not exceed 8 feet.

**EXAMPLE:**

California Palace of the Legion of Honor, San Francisco, California



Legion of Honor Memorial, originally built in 1922. The construction of new galleries underneath the existing courtyard required shoring the perimeter of the building with conventional soldier beams, tiebacks and lagging. The courtyard colonnades, the entrance arch and the porch structure of the building needed to be supported during construction. The contractor supported the structures with needle beams spanning between drilled soldier beams and/or existing walls. The structures were jacked to transfer the load to the underpinning elements. New service and ventilation tunnels were added inside and underneath the existing building which required underpinning a total of 46 columns with load of up to 250,000 pounds.