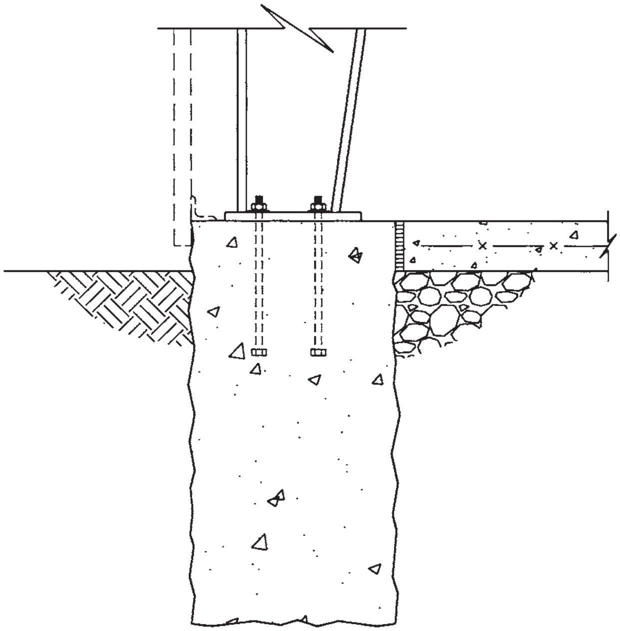

FIGURE 12.25 Mass foundation (formless footing).

finishing at least the top 4 in of the concrete, for a more refined appearance and to reduce rainwater intrusion into the excavation.

From a structural standpoint, the mass foundations certainly can be designed to be large and deep enough, as needed for resistance to uplift and lateral loads.

12.6 ANCHOR BOLTS AND BASE PLATES

Anchor bolts, or anchor rods, as the AISC prefers to call them, transfer uplift and shear forces from building columns to foundations, acting as a crucial link between the domains of the metal building manufacturer and the engineer of record. Some of the pitfalls and misconceptions in specifying anchor bolts for metal building systems are addressed in Chap. 10; here, our focus is primarily on the technical aspects.

12.6.1 Anchor Bolts: Function and Types

Anchor bolts serve two basic functions:

1. Positioning the column in the proper place and keeping it stable during erection. The minimum number of anchor bolts for metal building columns, per OSHA regulations for steel erection, is four. The only exception made by OSHA Safety and Health Standards for the Construction Industry, 29 CFR 1926 Part R, Safety Standards for Steel Erection, applies to posts. OSHA

defines a post as an "essentially vertical" structural member that either "(1) weighs 300 lbs or less and is axially loaded, or (2) is not axially loaded, but is laterally restrained by the above member." In the past, the minimum number of column anchor bolts was two, and some metal building manufacturers' details still reflect the old practice.

2. Transferring lateral and uplift loads from the column to the foundation. Anchor bolts have a limited capacity to transfer shear, and for very large lateral reactions it may be better to use shear lugs instead.

Most project specifications require that a template be used to set the bolts. The anchor bolt steel should conform to a relatively new specification ASTM F1554, *Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength,* which has displaced the earlier ASTM A307. As the title indicates, the new specification includes three grades of steel, but the most common still uses the traditional 36-ksi grade. This grade is relatively inexpensive and weldable, which is important should field corrections and bolt extensions become necessary. The higher grade 55 can be safely assumed to be weldable only if special weldability and carbon equivalent requirements are specified.

Some engineers long for high-strength steel and specify anchor bolts of ASTM A 325, which is incorrect and should be avoided. ASTM A325 is typically used for high-strength bolts connecting steel to steel, not steel to concrete, with the maximum bolt length normally limited to 8 in—too short for anchor rods. As we discuss below, the strength of the bolt material is often less critical than the strength of concrete that holds the bolts.

Anchor bolts derive their holding strength from bearing of their bent or enlarged ends against concrete. Excepting the cases of postinstalled adhesive and grouted-in anchors, any contribution of bond between the bolt shank and concrete is neglected. Depending on the configuration of their embedded ends, anchors are called L bolts, J bolts, headed bolts, and bolts with bearing plates. Of these, L and J bolts used to be most popular until it was demonstrated that L bolts were less effective in resisting slip than headed bolts.[12] Hooked anchors tend to fail by pulling out of concrete—an unsettling mode of failure, as the author has witnessed. The bolts with a bearing plate at the end, once the darlings of structural engineers, also fell out of favor once it was recognized that the larger the plate, the bigger the plane of weakness it introduces into concrete.

Shear lugs—short flat bars welded to the underside of column base plates—are used to transfer shear forces to concrete without reliance on anchor bolts. To be effective, shear lugs need to be properly confined[13] and require special formwork inserts. Shear lugs can be used most effectively in resisting very large lateral loads and are most commonly encountered in pre-engineered buildings on the West Coast.

As the evidence accumulated that properly embedded and confined headed anchor bolts were able to fully develop the tensile capacity of regular and high-strength bolts,[14] headed bolts gradually became the anchors of choice.

12.6.2 Headed Anchors: Design Basics

A headed anchor located far away from an edge of concrete and subjected to pullout will develop a "concrete failure cone" (Fig. 12.26*a*). Whenever several closely spaced anchor bolts are used, as is the case with most practical designs, their failure cones partially overlap (Fig. 12.26*b*). The headed anchors located near an edge of concrete wall or pier will develop only a partial concrete failure cone (Fig. 12.26*c*). The theory and experimental data for all these models may be found in Refs. 13, 14, and 15.

Tension capacity of a headed anchor depends on two factors: the tensile strength of the steel shank and that of the concrete failure cone. It is easy to increase the former by simply using as many and as large bolts as required by design, but it is rather difficult to increase the latter. To enlarge the size of the concrete failure cone, longer anchor bolts are needed or the bolts must be spaced farther apart. To ensure some measure of ductility and prevent brittle failure of concrete, the standard practice is to