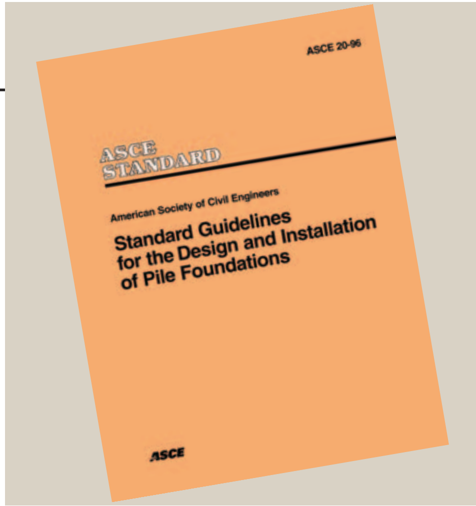

ASCE Standard 20-96

Guidelines for the Design and Installation of Pile Foundations

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Introduction

Most Structural engineers are familiar with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, but few are aware of ASCE 20, *Standard Guidelines for the Design and Installation of Pile Foundations*. This standard should be in the library of any structural firm that engineers deep foundations.

Driving steel H-piles with a vibratory hammer, and seating with an impact hammer.

History

When I started in this business in the late 1950's, we were called Soils and Foundations Engineers. We worked directly for owners on dams, tunnels, landslides, mine subsidence, blasting claims, etc., but on the foundations for buildings and other structures, we usually worked directly for and were paid by Structural engineers out of their pocket. The Structural engineers of that day were excellent piling designers.

We drilled test borings, determined the pile driving criteria by counting the hammer blows per foot on the steel casing, and measured pile capacity with the Engineering News Formula. Load tests always had a safety factor of 2.0.

Shortly after the Love Canal disclosure, many of the former Soils and Foundations engineering firms switched their focus to Environmental engineering, and ASCE changed our name to Geotechnical engineers (I voted against the change). Now the Geotechnical firms usually work directly for the owner or his representative.

ASCE Standard 20-96

ASCE Standard 20-96 brings the technology of pile driving up to date.

The Wave Equation has replaced the Engineering News formula as the primary method of predicting pile capacity (and driving stresses). The Wave Equation more accurately predicts pile capacity, particularly with modern pile driving hammers that are more efficient than the older steam, diesel or air hammers. The use of the Wave Equation can often prevent the need for overdriving piles, and results in a reduction in pile damage.

Expensive static load tests can be supplemented, and even replaced, by dynamic load testing using the Pile Driving Analyzer. With this equipment, a hand-held hammer is the heaviest tool needed to determine pile integrity.

New types of piles are included that give the engineer a better selection of deep foundation solutions. In addition to covering timber, steel, and concrete piles, the standard also includes mini-piles, auger cast piles, pressure injected footings, mandrel-driven shell piles, and driven caisson piles.

The standard includes guidelines for calculating allowable design stresses for each of the pile types. Pile shaft strength is evaluated by Allowable Stress Design (ASD) methods. Load and Resistance Factor Design (LRFD) methods are not included. Consideration is given to stresses resulting from pile driving and handling as well.

The standard discusses down-drag loads (negative skin friction) exerted on piles by the surrounding soil as the soil consolidates. These down-drag loads can be considerable on sites where loose or compressible soils are overlain by denser soils.

Piles can experience relaxation where the pile bearing capacity diminishes with time. This can occur when piles are end bearing on shale or dense, saturated silts or fine sands. Piles may also experience soil freeze or setup where the bearing capacity increases after pile driving stops. Restriking of a representative number of previously driven piles is recommended to determine if relaxation or setup is occurring.

The standard covers construction related design considerations including driving stresses, location and axial alignment tolerances, obstructions and hard strata, design modifications due to field conditions, reduced cross-section areas, pile spacing, pile caps and bracing, splices, etc.

Installation guidelines for pile driving include gravity, air, steam, hydraulic, diesel and vibratory hammers. Augered pressure grouted pile equipment is described, including mixing and pumping grout. Pre-excavation methods such as spudding, jetting, augering, and wet-rotary drilling are permitted if approved by the engineer. Methods of placing cast-in-place concrete are specified. Heaved, relaxation and set-up are defined. A short section on obstructions is included. Probe piles, bent dog-legged, or collapsed piles and pile installation and testing records are included.

Driving a pre-stressed concrete pile with a hydraulic hammer.

Proposed Changes to ASCE Standard 20

The committee has worked for several years to fine-tune and update ASCE Standard 20. The revisions will soon be balloted, and it is likely that the revised standard will be released as ASCE Standard 20-04. Some of the proposed changes include:

1. Pile loads are redefined to mention that Structural engineers convert the building Load and Resistant Factor Design (LRFD) to working or service loads for piles design using Allowable Stress Design (ASD).

2. Design Load is redefined to include downdrag; Service or Working load is redefined to exclude downdrag.

3. New methods of pile testing are mentioned.

4. Drilled Displacement piles are added. They are similar to auger-cast.

5. Micro-piles are added, with equations for deriving compressive and tensile loads. The original Mini-Pile section is still included. Other pile sizes were changed because Micro-piles are often less than 8-inch diameter.

6. Jacked piles are added, including allowable stress analysis and loading procedure.

7. The committee will soon vote on possibly revising the section on Safety Factors. Piling contractors are accustomed a load testing to TWICE the design load. The Engineering News formula has a theoretical Safety Factor of SIX. Piling failures are few and far between. Now we have Pile Driving Analyzers, Integrity testing, Wave Equations, etc., that should allow for lower safety Factors.

Conclusions

In the early 1960's, I was taught that ½ the strength of materials could be used for structural design in members above the ground because they could be seen, and 1/3 below the ground where the piles were out of sight. Not much has changed, as most of the design stresses given for piling are still 1/3 the strength of material. But some things are new.

In the early 1960's, the steel H-Piles driven to end-bearing in glacial till at the Albany Mall in New York had to be re-driven several times. My MS thesis advisor told me to look in a textbook by Scott for the answer, i.e., negative pore-water pressure. The shearing strength of dense over-consolidated silty clayey sand and gravel simply relaxed after the piles were seated and the water

Driving timber piles with a hydraulic hammer.

pressure normalized. None of the information on pile redriving was published for years, but now discussion of *relaxation* is included in ASCE 20.

Contractors know that set-up occurs when piles are driven to a pre-determined depth in the varved silts and sands of the New Jersey Meadowlands, Flushing Meadows, NY, and New Haven, CT. Pile driving resistance increases after initial pile driving has stopped, and set-up can save the owner considerable costs by using shorter piles. *Set-up* is also included in ASCE 20.

Now we have a *Wave Equation* to replace the Engineering News formula. The advantage of a Wave Equation analysis is knowing in advance the anticipated theoretical driving stresses for a given pile and hammer combination. The *Pile Driving Analyzer* provides actual driving stresses and pile capacity, but must be adjusted for relaxation and set-up conditions.

Auger-cast piles are included in ASCE 20. Leading auger-cast companies had record sales in 2002, and anticipate increased business in 2003. Inspecting an excellent auger-cast contractor in NY's Chinatown was a real pleasure, as was conducting a load test for a Drilled Displacement pile on a job in Norwalk, Connecticut. Very little if any soil was brought to the surface with the Drilled displacement pile, a real plus for environmental considerations.

Baur BG-22 Drill Rig and Fixed Lead Crane Attachment Drills

Micro-piles are absolutely amazing, as they cut through rock as if it were butter. They remind me of a percussion drill, except air or water is used as an aid in drilling. This is a tough job for inspectors because of problems determining the top of rock, but experienced contractors can be trusted. Twelve-inch diameters are becoming common, thus "mini" has been dropped except for piles mostly used in Texas for construction with expanding soils.

The old stand-by, the *driven pile*, is still being used on most jobs, often with new and very efficient hydraulic hammers. *Hydraulic hammers*, introduced in the USA about 10 years ago by my present employer, Norwalk Marine Contractors, are about 50% more efficient than air/steam hammers. Engineering News formula and the Wave Equation must be revised when using the hydraulic hammer

With new piles, improved hammers, and computerized testing and analysis, structural engineers can find a useful reference in the ASCE 20, Standard Guidelines for the Design and Installation of Pile Foundations.

James S. Graham, P.E., Chairman, ASCE Pile Foundations Standards, has 50 years experience in pile foundations. Mr. Graham has worked for: Corps, Ackenheil, US Steel, Meuser Rutledge, TAMS, Bechtel, NTPC, Heller and Johnson (Principal. Jim currently is currently employed with Norwalk Marine Contractors.

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