



# Seismology and Structural Standards Committee

Seismology Publication

April 2005

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## Micropile Construction, Design and Code Provisions

### Scope:

This white paper presents a brief description of the micropile system, micropile design and construction practices, and describes why tailored seismic code provisions need to be developed. SEAONC Seismology and Structural Committee endorse the

pursuit of such code provisions and invites members with knowledge of the micropile system to participate in code provision development by contacting the SEAONC Foundation Subcommittee, the initiators of this paper.

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### Symbols and Abbreviations:

*See Publication for Symbols and Abbreviations (in context)*

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### Commentary:

Although the use of micropiles extends back decades within California, only within the last year has the Seismology Committee considered the seismic performance of the system. The design methods and code provisions used in the design practice vary widely. Provisions developed more recently have been developed without SEAONC's input. On initial review of the micropile system one finds that the system does not conform to

current deep foundation code provisions. Namely, the reinforced concrete section of a micropile is over reinforced and lacks any confinement or shear reinforcement for part or in some cases the full pile length. This paper brings these issues to the engineering community in an endeavor to solicit support to develop sorely needed micropile seismic provisions.

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### References:

*Micropiles Design and Construction Guidelines*, US Department of Transportation, FHWA, report number FHWA – SA – 97 – 070, June 2000.

*Draft AASHTO LRFD Supplement for Micropiles*, ADSC Micropile Committee, 2003.

*Guide to Drafting a Specification for High Capacity Drilled and Grouted Micropiles for Structural Support (draft version)*, Deep Foundations Institute, Micropile Committee.

*Micro Pile Reinforcement Systems and Corrosion Protection*, Horst Aschenbroich, Dipl. Ing., presented at the ADSC Micro-Pile Seminar, Charlotte, NC, November 13, 2001

*Guide to Drafting a Specification for High Capacity Drilled and Grouted Micropiles for Structural Support*, Deep Foundations Institute, Micropile Committee, First Edition.



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## Authorship:

This publication represents views endorsed by the Seismology Committee. It may differ from the views, methods, policies and interpretations of some building authorities. Engineers are cautioned to ascertain such views, methodologies, policies and interpretations in advance of design.

The document was approved by the Seismology Committee March 2005.

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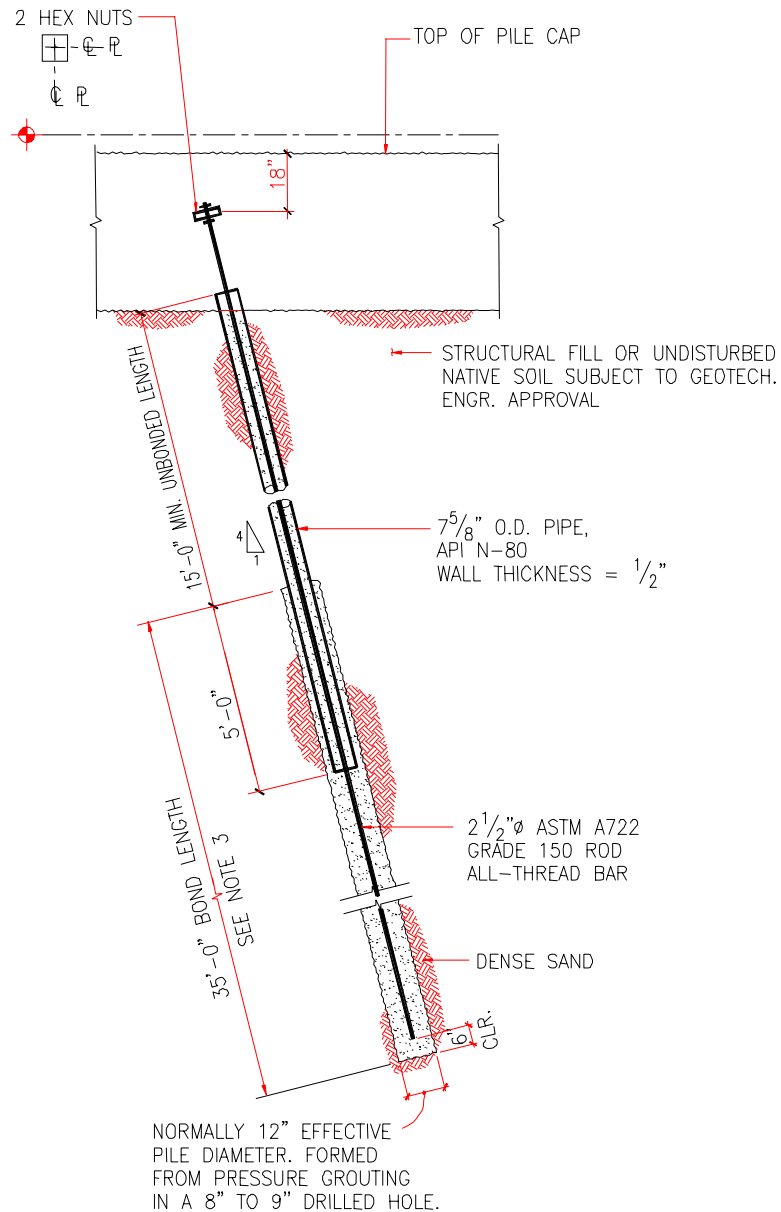
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## 1. Objective

Present a topic for discussion in the hope that code provisions will be developed for Micropile construction. Such provisions are being developed by others, but are considered by SEAONC/SEAOC lacking in requirements for regions of seismic activity, such as California. This paper presents a broad description of the deep foundation system's history and details, today's design and construction practice, and available and forthcoming specifications and code provisions. The paper closes with a suggested list of issues to be considered in the development of Micropile code provisions.



**MICROPILE DETAIL**



## 2. Overview

Micropiles, also referred to as Minipiles or Pin Piles, are a deep foundation system frequently used for seismic retrofit and are now becoming cost efficient for new construction. The system originated in Europe some 50 years ago with a simplified version consisting of a single bar encased with cement grout placed into a small diameter drilled hole. Practice today provides several types of installation configurations and procedures, depending upon the application and ground conditions, and is briefly discussed herein; for detailed information please refer to FHWA-SA-97-070, June 2000. A typical configuration is depicted above:

It is surprising how there is widespread usage of the system, given that Micropiles do not conform to the 2001 California Building Code due to the following aspects:

- No confinement reinforcement
- Potentially excessive concrete shear stresses
- Excessive longitudinal reinforcement content

All three non-compliance issues may contribute to poor seismic performance, hence these conditions are not permitted by the CBC or used in good practice; so why are Micropiles being used?

## 3. Micropile Details

Piles are generally classified as a displacement or replacement pile, which implies whether the soil is displaced or removed during pile installation. A driven pile is a displacement, whereas a drilled pier/shaft is a replacement pile. Micropiles are drilled and grouted replacement piles. The top portion (typically 15 feet or more) of the pile is formed with a nominally 4 to 12-inch diameter steel pipe filled with grout and reinforcing bar(s). The bottom portion is uncased. This uncased portion of the pile is well beyond the point where flexural actions occur and is nominally an 8 to 14-inch diameter reinforced grout (and grout enhanced soil) pile.

In conventional cast-in-place replacement piles, the concrete transfers most of the applied compressive load to the surrounding soil; a larger cross-sectional area, which increases the concrete-soil interface and compression areas, achieves increased compressive capacity. Micropiles use innovative and vigorous drilling, grouting (neat cement concrete placement under pressure), and high pressure post-grouting (if required) methods to develop concrete-soil interface stresses several times that achieved with conventional cast-in-place methods. To exploit this benefit, steel elements with high strength capacity and stiffness are used to resist the applied loads. These steel elements may occupy as much as one-half the hole volume.



The efficiency of the soil-structure stress transfer is reflected in the construction cost, hence the popularity of the system. Furthermore, the ability to install Micropiles in small and height-restricted spaces makes the system ideal for retrofit and refurbishment projects. The pile region devoid of shear or confinement reinforcement is beyond the presumed flexural zone of the pile, therefore is acceptable even in regions of high seismicity with a caveat. The ground conditions should be somewhat uniform and not prone to imposing flexural action on the pile assembly due to differential ground deformations, which requires a geotechnical engineer's review.

The use of a steel pipe at the top of the pile affords the confinement and enhances the lateral shear capacity of the pile, which is subject to actions similar to that applied to a column or beam element. For the uncased zone, the demand actions on the single or group of bars encased in unreinforced grout are limited to axial forces. The high overburden pressure and competent soil material over the bonded length afford the confinement and lateral stability required for the axial load-resisting element. Because this zone is influenced by soil-structure interaction, structural element code provisions are not applicable.

#### **4. Micropile Design and Construction Practice**

In practice, code requirements have not been viewed as applicable to Micropiles. Consequently, Micropiles are typically designed and detailed as a design-build item by the contractor rather than the design team. There are no code provisions for the designer or the building official to follow to ensure that all design issues are considered. Specifically, the system's design is typically based on axial load and deformation performance requirements at the top of the pile without, perhaps, consideration to:

- Type and magnitude of design actions at pile depth
- Rotational demands at the head/top of the pile
- Shear transfer between pile and pile cap
- Corrosion vulnerability

The pile has no confinement or shear steel for most of the pile's bonded length, atypical for other types of foundations in regions of moderate to high seismicity. Likewise, corrosivity of the native soils is another aspect that requires consideration but is believed to be overlooked sometimes.

Given that Micropile design and construction practice is not regulated and that the system is non-compliant with the CBC, development and implementation of Micropile code provisions would be beneficial for the Micropile industry, designers, contractors, and building officials, as well as enhancing public and/or user's safety.



## **5. Forthcoming Micropile Construction Specifications & Code Provisions**

### **5.1 Specifications**

Significant effort within the last decade by the Micropile construction industry has resulted in two documents, a draft AASHTO LRFD-based Micropile Specification (non-building application) and “*Guide to Drafting a Specification for Micropiles*” (building application). FHWA has also produced “*Micropile Design and Construction Guidelines*.”

The International Association of Foundation Drilling (IAFD) and American Drilled Shaft Committee (ADSC) formed a Micropile Committee that prepared a draft Micropile AASHTO LRFD Specification in 2003. The specification is primarily used for non-building applications and is in LRFD format. This document has been submitted for approval to AASHTO T-15 Subcommittee; approval is pending. From 1996 through 2001, the Deep Foundations Institute (DFI) Micropile Committee developed a design guide for preparing a Construction Specification for Micropiles. The design guide was endorsed in 2001 and updated from 2001 through 2003 by the Joint ADSC-IAFD Micropile Committee. This document is complete and can be obtained from DFI.

Lastly, the above committees are in the process of developing a Micropile Specification for inclusion into the 2006 International Building Code (IBC). Completion of this document is imminent, however the Foundation/ Seismology Committee has not been able to have revisions made to this document.

### **5.2 Codes**

Current and possible future codes (2001 CBC, 2003 IBC, 2003 NFPA 5000 and ASCE 7-02) were reviewed to determine if Micropiles met code provisions. Generally, the system does not fall under a code-defined pile classification type, hence clauses from different pile types were considered. Based on review of these codes it is clear, but not surprising, that Micropiles could not satisfy the following: maximum reinforcement limits, shear and confinement reinforcement detailing requirements, allowable structural steel stress limits, and other prescriptive requirements.

## **6. Recommendations for the Development of Micropile Code Provisions**

Given that Micropiles are an undefined system and yet are widely used, code provisions are required to regulate Micropile design and construction, particularly when used for seismic resistance applications. The design process, hence code provisions, should address the following issues:

- 1) Shear, flexural and axial actions of the steel pipe encased portion (top) of pile;
- 2) Shear, flexural and axial actions of uncased portion (bottom) of pile;
- 3) Axial and shear transfer from pile cap to pile;
- 4) Pile head rotation;
- 5) Anchorage of central bar to pile cap;



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- 6) Pipe and rod reinforcement materials, configurations and splices;
- 7) Kinematics of raked piles;
- 8) Corrosivity.

In such applications a capacity design approach should be considered and, above all, be consistent with other types of foundation systems.