GEOTECHNICAL PRACTICE PUBLICATION NO. 6

GeoTrends
The Progress of Geological and Geotechnical Engineering in Colorado at the Cusp of a New Decade

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PROCEEDINGS OF THE 2010 BIENNIAL GEOTECHNICAL SEMINAR

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Colorado Association of Geotechnical Engineers

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Preface

Like our dynamic earth, the practice of geotechnical engineering is always changing. Like the wind slowly carving a stone, we tweak methods developed by the soil mechanics pioneers. Like a massive rockslide, we switch from rules of thumb to detailed computer models. Like a fault, trending across the arid west, our practice seeks out weaknesses in our knowledge and technique and uplifts them to new levels of understanding. This book celebrates these GeoTrends as its papers reveal the changes in shoring and foundations, explore the role of sustainability and energy efficiency, expand our techniques for slope stability evaluation, and tie together the past and present as geophysical methods are used to locate the underground workings designed and built by our geo-ancestors.

Since 1984, the ASCE Colorado Section's Geotechnical Group, in collaboration with the Rocky Mountain Section of the Association of Environmental and Engineering Geologists and the Colorado Association of Geotechnical Engineers, has organized a biennial series of geotechnical seminars on a wide variety of themes that have been attended by as many as 270 civil/geotechnical engineers, geologists, and other geo-professionals. The geotechnical seminars have been held at area universities or hotels and have offered the opportunity for sharing ideas and experiences among Colorado's diverse geo-disciplines. Since 2004, ASCE's Geo-Institute has published the papers of these seminars in Geotechnical Practice Publications, allowing the experiences to be shared with a worldwide audience.

The GeoTrends Steering Committee convened in August 2009 and held monthly meetings to plan for the 2010 Biennial Geotechnical Seminar. The Steering Committee members included Joseph Kerrigan (Conference Chair), Dustin Bennetts, Mark Brooks, Robin Dornfest, Darin Duran, Dr. Christoph Goss, Joels Malama, Dr. Bill McCarron, Minal Parekh, Becky Roland, Keith Seaton, Jere Strickland, David Thomas, Mark Vessely Chris Wienecke, and Richard Wiltshire.

Christoph Goss, Joe Kerrigan, Joels Malama, Bill McCarron, and Richard Wiltshire

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Acknowledgments

The GeoTrends Steering Committee wishes to take this opportunity to thank all of the authors and reviewers of our papers, which are herein presented as Geotechnical Practice Publication No. 6. The authors have spent many hours in preparing and finalizing their papers, which will be presented at the 2010 Biennial Geotechnical Seminar on November 5, 2010. These papers have been reviewed by a volunteer group of Denver area geo-professionals who put in their valuable time and helped make these papers even better. The Geo-Institute's Committee on Technical Publications completed its review of our GeoTrends papers in a very timely manner and their adherence to our aggressive publication schedule is greatly appreciated. We would also like to acknowledge the assistance of Donna Dickert of ASCE's Book Production Department for putting this publication together.

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Thirty Years of Excavation Shoring Design and Construction Progress in Denver, Colorado

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ABSTRACT: Schnabel Foundation Company began excavation shoring design and construction in the Denver area in May of 1979. From this first project at Writer Square to the present, hundreds of shoring projects have been completed throughout the region for commercial, residential, government, health care and transportation works. Some of the shoring systems used include driven sheeting, drilled sheeting, internal bracing, soil nailing, underpinning and micropiles.

There have been changes and improvements in many aspects of the work, including design procedures, equipment, materials, labor, and other means and methods associated with the work. There are also new challenges that have developed, such as fiber optic lines, increased utilities and directional drilling, light rail, etc. There have also been aspects of the work that have remained relatively unchanged, such as soil conditions, worker safety, etc.

This paper describes some of the history and practices in design and construction of excavation support systems, specific to the Denver, Colorado area.

INTRODUCTION

The selection and design of an excavation shoring system is comprised of many variables. First and foremost, the system must result in a reliable, safe system to protect people and property. Second, the system should be compatible with the site specific soil conditions. Third, the system should be economical, and efficient to build.

The Denver Downtown area, including Lower Downtown has seen continued growth, with occasional slow periods associated with economic conditions. For most projects some portion of the structure is frequently constructed below grade, typically for parking facilities, and the structure typically extends to the property limits. Beyond the property limits, improvement such as existing buildings, utilities, roadways, etc. may exist. Therefore, some type of shoring is used to minimize the lateral limits of the excavation and maintain uninterrupted service for adjacent property users.

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TYPICAL SUBSURFACE CONDITIONS

The Downtown area subsurface profile is generally comprised of two soil types. The upper soils consist of alluvial sands and gravels underlain by the Denver Formation. The depth of the alluvial material varies throughout the area and ranges in depth from about six meters (20 feet) and extends to depths in excess of eighteen meters (60 feet). The material ranges in density from loose to very dense and is typically poorly graded with very minimal fine material.

The Denver Formation typically consists of weak to moderate cemented sandstone and claystone bedrock. This material extends to depths well beyond the impact of most shoring projects. The bedrock is generally impervious, however groundwater is frequently found in the bedrock and the water table in the alluvial material varies with proximity to recharge sources and is typically about one meter (3 feet) above the bedrock. Groundwater is also found in perched zones in the alluvial material.

For excavation shoring, both materials offer unique qualities and challenges for both design and construction. The alluvial material tends to cave and collapse during beam drilling and requires slurry drilling to stabilize the drill hole. If the drill depth extends to the bedrock, casing is required as the bedrock cannot be drilled efficiently under slurry.

The alluvial material has a short standup height during excavation and collapsing in common. To minimize the caving, shorter excavation lifts are done, or soil mixing may be done between soldier beams prior to the start of excavation.

SHORING SYSTEMS

The most common shoring system used in downtown Denver has been soldier beam and lagging. For excavation depths up to about four meters (13 feet), the soldier beams are typically cantilevered. Deeper excavations utilize tiebacks for lateral support. Other systems have been used, such as soil nailing, secant and tangent pile walls, and sheet piling. Constructability, economics, and other site specific requirements have generally dictated the use or lack of use of these other systems.

DESIGN METHOD

Many references and design guidelines are available for determining the lateral earth pressure for the shoring system. Most of the projects that have been designed by Schnabel Foundation Company have utilized an empirical lateral earth pressure envelope similar to those recommended by Harry Schnabel (1982). All of the projects have been completed with out failure or other excessive movement. All the monitored projects have performed well within the expected movement ranges.

Important aspects of the shoring design are the building foundation layout and the foundation construction method. The soldier beams are spaced to minimize interference with the construction of the new building foundation. In Denver, most buildings are constructed on drilled shaft foundations. The soldier beams are spaced around the drilled shaft locations to avoid drilling the caisson directly in front of the toe of the soldier beam.

Tiebacks are used to provide lateral support when an easement from adjacent property owners is obtained and when existing improvements do not prevent such installation. When tiebacks cannot be installed internal bracing may be used to provide lateral support.

FIG. 1. Internal bracing and wale, left wall. Tiebacks, right wall, Denver, CO

INSTALLATION METHODS

Driven Soldier Beams

In 1979, Writer Square, the first project that Schnabel worked on, the shoring system was installed using driven H-piles with pressure injected tiebacks. The tiebacks were connected to the soldier beams using a waler placed on the face of the soldier beam. The face of the shoring was located about two meters (6 feet) from the outside face of the building to allow adequate space for access between the formwork and the shoring and waler as the new building would be constructed using a conventional double sided form system. The void between the building and the shoring was then backfilled with soil, gravel, or other material as specified by the geotechnical engineer.

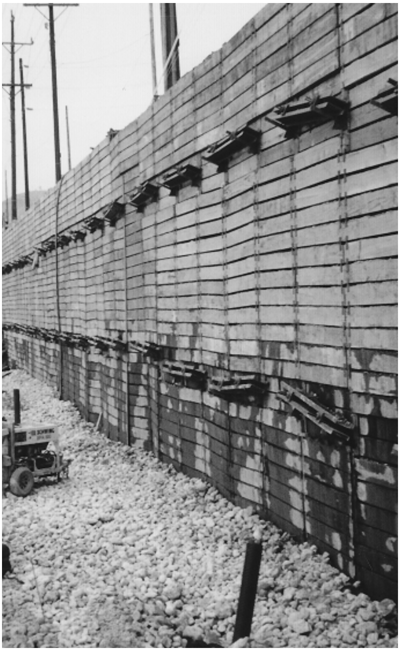

FIG. 2. Driven soldier beams with walers

Driven soldier beams can be an economical method to install soldier beams and is frequently used in many other parts of the country. In the Denver area, driven soldier beams were used until the mid 1980's, but use has largely been discontinued for the last twenty plus years.

Some of the reasons driven soldier beams are seldom used include:

1. Piles cannot be driven in the bedrock, which is regularly encountered within the required depth of the soldier beam
2. Pile driving equipment is limited in it's availability in the region as drilled shaft foundations are much more common and suitable to the local soil conditions
3. Off wall line shoring requires one to two meters (3 to 6 feet) of space beyond the building/property lines, which space typically includes utilities, buildings, or other constraints
4. Tieback connections may be more expensive
5. Shorter spans between piles, 1.75 to 2.5 meters (6 to 9 feet) on center, requiring more piles, tiebacks, and lagging connections
6. Possible vibrations from pile driving equipment may be transmitted to adjacent structures