GEOTECHNICAL SPECIAL PUBLICATION NO. 74

ASCE

Guidelines of Engineering Practice For Braced and Tied-Back Excavations



GEO INSTITUTE

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Guidelines of Engineering Practice For Braced and Tied-Back Excavations

By the Committee on Earth Retaining Structures
of The Geo-Institute
of The American Society of Civil Engineers



Published by
ASCE American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191-4400

Abstract:
When an excavation is made in soil or rock, materials adjacent to the cut face lose their natural lateral support. It then becomes necessary to support the excavation by using braces and tiebacks. These will provide the lateral restraint needed for safety. These guidelines have been prepared to aid civil engineers in making the essential decisions regarding construction safety and excavation activities. They are also intended to provide information and conceptual orientation for owners, funding agencies, contractors, and engineering and architectural staff.

Library of Congress Cataloging-in-Publication Data

American Society of Civil Engineers. Committee on Earth Retaining Structures.
Guidelines of engineering practice for braced and tied-back excavations / by the Committee on Earth Retaining Structures of the Geo-Institute of the American Society of Civil Engineers.
p. cm.
Includes bibliographical references and index.
ISBN 0-7844-0293-0
1. Excavation. 2. Retaining walls. 3. Shoring and underpinning. I. Title.
TA730.A44 1997 97-36244
624.1'52--dc21 CIP

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Library of Congress Catalog Card No: 97-36244
ISBN 0-7844-0293-0
Manufactured in the United States of America.

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PREFACE

Work on these guidelines was initiated at the suggestion of the late George W. Sowers, then chairperson of the Earth Retaining Structures Committee of the Geotechnical Engineering Division, at the ASCE *1970 Specialty Conference on Lateral Stresses in the Ground and Design of Earth Retaining Structures*. The work was continued by successive committee chairpersons including: James P. Gould, Harry W. Schnabel, Thomas D. O'Rourke, Donald R. McMahon, Lawrence A. Hansen, and Richard J. Finno. It was originally intended to take the form of an ASCE manual, but the Committee found that consensus could not be reached among members representing different industry interests on many fundamental issues. Therefore, it was finally agreed that guidelines could best express the difference in viewpoints while allowing the user to choose an appropriate approach for a project without the constraints of a manual or a standard. These guidelines are intended for the use of the professional civil engineer involved in the work of a braced or tied-back excavation. This document is not a standard.

Many members of the Earth Retaining Structures Committee contributed comments and concepts to the making of the Guidelines. Those who were particularly helpful in providing text sections and in reviewing text sections include the following members: H. A. Aldrich, R. A. Alperstein, W. J. Armento, R. A. Bell, G. W. Clough, R. D. Darragh, J. P. Gould, L. A. Hansen, A. J. Nicholson, T. D. O'Rourke, H. W. Schnabel, W. L. Schroder, R. vanLeuwen, and D. Weatherby. Text preparation, figure preparation, and final editing of the report were performed by Mary J. S. Roth and Thomas F. Boni.

CHAPTER 1: INTRODUCTION

1.1 Function of a Braced or Tied-Back Excavation and Role of These Guidelines

When an excavation is made in soil or rock the materials adjacent to the cut face lose their natural lateral support. The deeper the excavation and steeper the cut, the greater is the stress unbalance caused by removal of lateral support. If the resulting shear stress exceeds the material's strength the mass can fail by sliding. Facilities or structures outside the excavation can be damaged, work within the excavation disrupted and personnel endangered. When it is impractical to provide slopes flat enough for safety, it becomes necessary to support the excavation. Braces and tiebacks replace the lateral restraint that was provided by material which was removed.

Excavation work, especially in urban areas, involves decisions about complex issues, such as construction methods, support loads, base stability, ground deformation, groundwater control, and influence on adjacent property. These guidelines have been prepared to aid the civil engineer in making such decisions. They also are intended to provide information and conceptual orientation for owners, funding agencies, contractors, and engineering and architectural staff.

The guidelines deal exclusively with braced and tied-back excavations utilized in construction of buildings or other civil engineering structures. Not included are the special cases of temporary support of tunnels or underground chambers, mines, cofferdams placed in open water, excavation schemes for quarries, permanent sloped open cuts such as for highways or site grading and problems of rock slope stability.

The guidelines do not cover trench support placed according to code requirements or empirical rules without engineering design. This omission is not intended to minimize the importance of trench construction and the potential for failure under these circumstances. However trench sheeting and bracing often are selected by a contractor based on experience without the participation of a professional civil engineer. For such a situation there are various standard rules in building codes or in Federal safety and health regulations. Such empirical rules are not included or utilized herein.

1.2 Characteristics of the Supported Excavation

The essential elements of an excavation support system comprise a wall, supports, and a reaction to or anchorage for the loads transmitted through the bracing. This

apparently simple arrangement has a number of features which distinguish it from ordinary civil engineering structures:

1. Installation of the support system is coordinated with the excavation and is generally built from the top downward. Excavation and support installation usually are performed in stages and the critical condition for various elements of the support system may occur at some intermediate stage during this construction.

2. The support system usually is temporary in nature with a life ranging from several months to several years. In special cases the wall of the excavation is incorporated into the permanent structure.

3. In some cases safety factors are lower and the stress levels higher than for a permanent structure. The choice of safety factor is influenced by the consequences of failure as they affect the work within the project and adjacent properties.

4. Deformation of the support system can be as important as its load-carrying capacity. Numerous instances have occurred where the braced excavation is safe against an overall failure but movements of the retained soil are unacceptable because of their effects on interior or exterior structures.

1.3 Difficulties with Supported Excavations

Braced and tied-back excavations may lead to difficulties. These problems usually fall in one of the three following groups.

1. Structural inadequacy of the support system which arises from one of the following:

    a. Errors in selection of earth or water pressures, including failure to consider special loadings such as heavy surcharges, an earth slope above the top of the support system, or insufficient passive resistance of interior berms.

    b. Oversights in structural design, often involving weakness of connection details and failure to take into account practical problems of installation.

    c. Inappropriate construction procedures, particularly careless installation of the support wall or failure to match elements of the bracing system.

d. Unforeseen adverse subsurface conditions.

e. Poor coordination with other construction activities in the interior of the excavation.

2. Excessive movement or deflection of the system may be a product of the structural weaknesses described above or one of the following:

a. Insufficient stiffness of the support system, including lack of fit of connections.

b. Inattention to support requirements during construction including failure to pre-load braces, over-deepening of excavation beneath support levels, delays in adding or supplementing support and premature removal of support.

c. Loss of ground from over-excavation made for placement of support wall or lagging, excessive lengths of slurry wall panels, or inadequate backfill of holes pre-drilled for piles.

d. Ineffective ground water control, resulting in piping of soil particles through openings in the support wall or "quick" conditions at the excavated subgrade.

e. The presence of deep soft clay soils beneath or in the lower portion of the excavation.

3. Movements of the surrounding ground caused by excavation and construction of the support system, but not related to the support system itself, can occur as follows:

a. Settlement due to the increase in soil effective stresses which accompanies drawdown.

b. Erosion or piping due to surface water runoff, ground water gradients, or utilities leaking into the excavation.

c. Settlement caused by pile driving, blasting, or mechanical vibrations in the construction.

d. Weathering or deterioration of soil and rock exposed in the cut face or at subgrade.

Many of these factors are interrelated. For example driving of steel sheet piling might settle loose sand retained by the bracing system. This settlement in turn

could break a water main in the retained sand. The consequent increase in water pressures or piping could damage the support system that has been selected under the assumption of a dewatered condition.

There are three spheres of exposure to damage: the working space within the excavation; areas immediately outside the excavation; and surrounding areas at some distance from the excavation. Within the excavation these hazards threaten those most directly involved in the project and ordinarily are the first concern of the designer. Within adjacent exterior areas there is the risk of injury to third parties plus damage to structures founded on or within soil and rock which are retained by the excavation support system. Their protection influences strongly the requirements for the excavation support scheme. Within the third sphere the risk is less but damage and nuisance may still occur. The ultimate impact can be serious because of the larger area involved and the likelihood that effects are unforeseen.

1.4 Assignment of Responsibility

Opinions diverge among engineers, constructors and public officials regarding assignment of responsibility for performance of an excavation support system. This is reflected in the following three general procedures for design and construction:

1. Design of the support system is by an agent of the owner of the permanent structure, generally by the structural engineer for the project, and it is executed by a contractor selected by competitive bidding or negotiation. Inspection of the work is by an agent of the owner.

2. Design and construction are by a contractor selected by the owner, either the builder of the permanent structure or a sub-contractor specializing in excavation and bracing work. Owner's agents provide only periodic inspection supplementing that of local building officials.

3. The excavation and support system are undertaken according to empirical rules embodied in building codes regulating such work and a professional engineer may not be involved. Inspection, approval or review is by representatives of the agency that administers the code.

Each of these procedures has advantages appropriate to certain building situations and each has it particular problems. In many projects elements of all three schemes are intermingled. In any case, results depend on the skill and integrity of those involved in the design, construction and in administration of the building code. The first procedure tends to keep the interest and liability of the owner under the owner's direct control. The second relies on the skill of a specialist

contracting organization throughout. For major work less reliance is being placed on code provisions, empirical design, and inspection by public agencies, as embodied in the third procedure.

1.5 Definitions of Parties of the Work

The parties involved in the work of braced excavation are referred to in subsequent chapters of the manual and are defined as follows:

Owner is the party sponsoring the new permanent construction which requires a braced or tied-back excavation. The owner engages design services in connection with the work and contracts with a builder for construction of the work.

Engineer-of-Record ordinarily is the professional civil engineer retained by the owner to design the permanent construction. Depending on local laws and the engineer's arrangement with the owner, the engineer may also be responsible for some elements of the excavation and support system design. The engineer's professional stamp appears on contract drawings relating to the excavation. The engineer stipulates the general requirements of the excavation and assesses its compliance with applicable codes. The engineer will also have a part in reviewing the contractor's shop drawings as the owner's representative.

Designer is the engineer, presumably a professional civil engineer, who is directly involved in technical decisions for the excavation. The designer may be working with the contractor or the engineer-of-record and is concerned ordinarily with technical aspects and not contractual or administrative questions.

Resident Engineer will direct the field inspection of a braced excavation. The resident engineer may be an employee of the owner or the engineer-of-record. The resident engineer is to see that specification provisions are followed and will be concerned with departures from the contract, field expedients, and alternative procedures. Ultimately, the resident engineer will share with the contractor much of the responsibility for field decisions. The resident engineer's staff includes inspectors whose work the resident engineer must oversee, who are technically qualified but are not necessarily professional engineers.

Geotechnical Engineer has evaluated site and subsurface conditions in advance of construction, has made recommendations regarding the permanent structure and has given criteria relating to the excavation and

support system. The geotechnical engineer would have been retained by the owner, the engineer-of-record or, less frequently, by the contractor.

Contractor has a contract with the owner for construction of the excavation support system. This may be the prime contractor or it may refer to specialist subcontractors involved in particular elements of the work, such as construction of the enclosing wall, interior excavation, underpinning, or tieback installations. The contractor may employ or retain the engineer who designs the excavation support system.

1.6 Objectives and Organization of the Guidelines

These guidelines do not advocate any single approach to carrying out the work of braced and tied-back excavations or the related assignment of responsibility. These guidelines describe various techniques used to support excavations, methods for design and potential difficulties. Recommendations are provided for dealing with problems or for anticipating them in specifications. Criteria that should be considered in a good design are outlined and conditions under which these criteria should be modified are pointed out. Ultimately the owner, engineer-of-record, specialized engineering consultants, contractor and the public building official all contribute to the safety and quality of the support system.

While there is no intent that the guidelines play a part in litigation, they might conceivably be utilized to challenge engineers' decisions in cases where damage has been suffered. *In this respect it is stated categorically that decisions of a professional civil engineer directly involved in the specific case should reasonably be assumed to take precedence over generalizations contained in these guidelines.*

Safety of the support system and the protection of facilities within and adjoining the excavation are a primary concern of these guidelines. However, the safety work rules and requirements that are within the purview of the Occupational Safety and Health Administration (OSHA) generally are not treated herein.

1.6.1 Readership. The guidelines are directed principally to civil engineers without distinction as to whether they are associated with the owner, design organization, contractor or public building agency. It is assumed that the engineers will have experience and competence in design, but may not possess specialized knowledge in geotechnical engineering. The guidelines are not intended to be a handbook for design to be used by those who have little knowledge of construction, structural design or geotechnical engineering. Although not a substitute for a building code, it is hoped that professional civil engineers on the staff of public agencies enforcing code provisions will find it useful. It is intended that the manual reflects what a group of specialists in this subject consider to be good engineering practice.

1.6.2 Organization of Contents. The main body of the manual consists of eight chapters. No attempt is made to present detailed technical information readily available in standard sources. References that are necessary to implement recommendations of the guidelines or which amplify important topics are listed at the end of each chapter.

Chapters 2, 3 and 4 treat background subjects: investigations, water control, design loadings, and stability considerations. These chapters address work which chiefly concerns the geotechnical engineer. Chapters 5, 6 and 7, on walls, internal support systems and tiebacks, respectively, relate primarily to the work of the designer. Chapter 8 deals with problems of installation, overall system stability and control of construction which are the concerns of the engineer-of-record, the resident engineer, and the contractor.