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by

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Abstract

An Examination of the Requirements for Fill Materials Included in Guide Specifications

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Guide specifications for fill materials are used in the preparation of the earthwork sections of specifications for individual projects. This report discusses the agencies that produce guide specifications for fill materials and the specific material characteristics that these specifications stipulate. A database of requirements for fill materials taken from 27 sources was compiled for this report. Data from this database were sorted and plotted and conclusions were drawn regarding the material characteristics stipulated by this set of specifications. Recommendations for writing guide specification are presented.

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Chapter 1: Introduction

Construction of retaining walls, embankments for roadways, earth dams, and utility trenches are just a few examples of projects where earth needs to be placed and compacted as fill. It is usually the job of the geotechnical engineer who performs the design to determine what kind of soil is suitable for the task. While each design deserves individual attention, "guide specifications" exist that can guide the engineer in the selection of a suitable fill material.

Guide specifications are also called "master specifications" or "standard specifications". These are templates that are used to create specific contract specifications. Contract specifications are the actual documents that a contractor and an owner agree upon for the performance of work for a specific project. While contract specifications are by nature precise and specific documents that are tailored to a specific project, guide specifications, which may be used for a multitude of projects, usually make more generalized recommendations.

The primary goal of the study described in this report is to determine what similarities and differences there are in various guide specifications for fill materials. Since the focus of this report is on fill materials, all references to guide specifications are references specifically to guide specifications for fill materials unless otherwise noted. Chapter 2 presents the agencies that use guide specifications and explains how their guide specifications can be obtained. Chapter 3 presents a database containing requirements for fill materials that was created during this study from a diverse collection of guide specifications.

Chapter 3 also explains how the database works and why the database design was chosen. Chapter 4 presents results of an examination and summary of the data in the database as well as any trends or lack of trends in the data. Chapter 5 contains the summary and conclusions for this study.

Chapter 2: Obtaining Guide Specifications for Fill Materials

This chapter describes some of the various agencies that maintain guide specifications and presents specific examples from each agency. Methods for obtaining copies of the guide specifications are presented. The guide specifications that are used in this study come from 5 major sources: federal, state, and municipal agencies, manufacturers, and textbooks. The specifications also exist in two main forms of media: electronic and printed.

ELECTRONIC VERSIONS

Electronic copies of guide specifications are distributed in four basic forms: Internet sites, floppy diskettes, compact discs (CD's), and digital video disks (DVD's).

Internet Sites

The Internet is the easiest and fastest way to obtain copies of guide specifications. The most important thing to know is where to look. Known Internet sites with guide specifications and recommended strategies for searching for additional specifications on the Internet are presented below.

Federal Level

At the federal level, Internet sites of U.S. government agencies provide a good place to look for guide specifications. Both military and civilian branches of the government use guide specifications and several post full versions of their

specifications on the Internet. Six government agencies and the corresponding links that lead directly to their guide specifications are listed in Table 2.1.

Table 2.1 - Federal Level Links to Guide Specifications for Fill Materials

Agency	Link
United States Army (Corps of Engineers)	www.hnd.usace.army.mil/ techinfo
United States Navy (Naval Facilities Engineering Command)	www.nfgs.navy.mil
National Aeronautics and Space Administration	www-de.ksc.nasa.gov/ specsintact/masters.htm
Federal Aviation Administration	www.faa.gov/ arp/5370-10a.htm
Department of Veterans Affairs	www.va.gov/ facmgt/standard/spec_idx.htm
Los Alamos National Laboratory	pelagius.lanl.gov:8080/ f/standards/f9stds/conspec/htmls/ stdspec.html

State Level

At the state level, the Internet sites of many state departments of transportation (DOTs) provide a good source for guide specifications. Two state agencies and the corresponding links to their guide specifications are listed in Table 2.2. Table 2.2 also provides a link to aid in the search for additional guide specifications at the state level.

Table 2.2 - State Level Links to Guide Specifications for Fill Materials

Agency	Link
Oregon DOT	www.odot.state.or.us/ techserv/roadway/specs/96book.htm
Florida DOT	www.dot.state.fl.us/ specificationsoffice/StandPage.htm
Homepages of DOTs for 47 US States	www.library.nwu.edu/ transportation/statedot.html

Municipal Level

Some cities and towns publish guide specifications on the Internet in the public works section of their Internet site. Two cities and the corresponding links to their guide specifications are listed in Table 2.3. Table 2.3 also provides two links to aid in the search for additional guide specifications at the municipal level.

Table 2.3 - Municipal Level Links to Guide Specifications for Fill Materials

Agency	Link
City of Lake Oswego, OR	www.ci.oswego.or.us/ engineer/spec.htm
City of Houston, TX	www.ci.houston.tx.us/ departme/works/ecre/e&cdocs
Homepages of the 50 Largest Cities in the United States	www.wplwloo.lib.ia.us/ 50cities.html
Homepages of Cities throughout the World	www.officialcitysites.com

Manufacturer Level

Manufacturers of geotechnical-related products often develop guide specifications describing the kind of fill materials that they have approved for use with their products. Two manufacturers and the corresponding links to their

guide specifications are listed in Table 2.4. Table 2.4 also provides a link to aid in the search for additional guide specifications at the manufacturer level.

Table 2.4 - Manufacturer Level Links

Company	Link
Geostone Segmental Retaining Walls	www.geostone.com/ tech.asp
Keystone Retaining Wall Systems, Inc.	www.keystonewalls.com
Mesa Retaining Wall Systems by Tensar Earth Technologies, Inc.	www.tensarcorp.com/ download/dg_mesa.pdf
The Internet Directory for Specified Construction Products™	www.4specs.com

Searching the Internet Further

Three search schemes were used in this study to locate guide specifications. The first scheme consisted of locating and using "directories". Directories are on-line listings that are manually compiled by people. The second search scheme used a "search engine". A search engine is different from a directory in that it does not depend on people to compile the listings, but instead searches the Internet itself to find new Internet sites not already in the database. The third search scheme used a special type of search engine called a "metacrawler". A metacrawler is actually a search engine that uses several other search engines to perform the actual search. It works by sending a search request to other search engines in parallel and then returns the listings from the other search engines.

In a search for guide specifications, there are many directories, search engines, and metacrawlers available for use by the three search schemes presented above. Depending on the search phrase used, some return useful listings and

some return listings that are not useful. In this study, no conclusion was reached concerning which directory, search engine, or metacrawler is the best to use for searching for guide specifications. All of the major directories, search engines, and metacrawlers seemed to work equally well for such a search.

The first step in searching for guide specifications on the Internet is simply to pick a specific directory, search engine, or metacrawler and examine the results to see if they are useful. If little or nothing of value is returned, another should be tried. A helpful site for deciding which directory, search engine, or metacrawler to use is [searchenginewatch.com]. This site lists and reviews almost every directory, search engine, and metacrawler on the Internet.

Once a directory, search engine, or metacrawler is chosen, one or more words to use in the search must be chosen. The following phrases seemed to work well for the searches performed for this study: "specifications", "guide specifications", "standard specifications", "master specifications", "construction specifications", "contract specifications", and "earthwork specifications".

Project Internet Site

As a part of this study, an Internet site was created. The site contains the complete database for fill materials presented later in this report and all of the guide specification links presented above. The address of the site is [www.ce.utexas.edu/stu/kochkm/home.htm].

Diskettes, CD-ROMs, and DVDs

An agency with a need for frequent and widespread use of its guide specification may publish the guide specification on either a CD-ROM or a DVD.

One of the best known examples of this is the Construction Criteria Base (CCB) published by the National Institute of Building Sciences (NIBS). It comes either as a set of seven CD-ROMS or as one DVD and contains guide specifications and design standards from 22 federal agencies and more than 110 other agencies. There is also a CCB Internet site at [www.ccb.org] where many of these documents are also available for download by subscribing members. Non-subscribing members can download a maximum of five of these documents which makes this a useful visit in a search for guide specifications.

PRINTED COPIES

Before the advent of the Internet, guide specifications were typically published by agencies as books or in three-ring binders. Even with the proliferation of electronic versions now available, many guide specifications are still published on paper.

States DOTs

Most, if not all, state DOTs publish their guide specifications every year in the form of a hard cover or soft cover book. The most recent versions typically cost less than $50. Depending on the intended use, individual copies may sometimes be obtained free of charge. Phone numbers and current prices can be found on the state DOT Internet sites.

Engineering Textbooks, Handbooks, and Manuals

While not guide specifications themselves, geotechnical engineering and construction textbooks, handbooks, and manuals can provide guidance on how to specify requirements for fill materials in guide specifications, and what those

requirements might be for common cases. Two textbooks that offer guidance for specifying fill requirements are the *Construction Guide for Soils and Foundations*, 2nd Edition[1] and *Design of Earth Retaining Structures*, Spring 1999 Edition.[2] One example of a handbook that offers fill specification guidance is the *Standard Handbook for Civil Engineers*, 4th Edition.[3] Finally, engineering and design manuals published by government agencies can also assist in determining requirements for fill materials. Two examples of such manuals are the Army Corps of Engineers Engineer Manuals [www.hnd.usace.army.mil/techinfo] and the United States Bureau of Reclamation Earth Manual [www.usbr.gov/tcg/earth/index.html]. These manuals can also be found on the Internet at the addresses given above.

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1 Ahlvin, Richard G., ed. and Smoots, Vernon Allen, ed. *Construction Guide for Soils and Foundations*, 2nd ed. New York: John Wiley & Sons, 1988.

2 Olson, R. E. *Design of Earth Retaining Structures: CE 387R, Spring 1999*. Austin, Texas: The University of Texas at Austin Co-op, 1999.

3 Merritt, Frederick S., ed., Loftin, M. Kent, ed., and Ricketts, Jonathan T., ed. *Standard Handbook for Civil Engineers*, 4th ed. New York: McGraw-Hill, 1996.

Chapter 3: A Database of Guide Specification Requirements for Fill Materials

On a conceptual level, the creation of a database for this study can be divided into two parts: defining the scope of the database and addressing issues of extracting, organizing, and compiling the data. These two parts are addressed next.

Defining the Scope

Two major decisions needed to be made at the outset of this study regarding the scope. First, the breadth of usage for different fill materials needed to be established. Second, the specific sections of guide specifications for fill materials that needed to be examined had to be determined.

After some deliberation, it was decided that the scope would be restricted primarily to fill materials used for embankments, retaining walls, bedding, and trenches. General fill and structural fill were also examined. Fill materials that involve chemical treatment of the fill, such as lime or cement stabilization, are excluded, except in a few specific instances where chemical treatment alters the allowable values for the types of fill requirements examined in this study. For example, the Louisiana DOT allows a higher plasticity index for embankment fills that are treated with lime. Base courses for roads and highways are also not considered in this study, nor are rip-rap, top soil, and working platforms.

After further deliberation, it was decided to focus on only those sections of the specifications that covered the characteristics of the fill materials. Sections

that specify procedures such as ground preparation before placement of the fill, compaction of the fill after placement, and testing of the fill before and after placement are not addressed in this study.

Issues of Extracting, Organizing, and Compiling Data

There are several challenges that must be dealt with when summarizing the content of a guide specification, comparing this summarized content with that from other guide specifications, and even when simply reading a guide specification. One obvious and inherent drawback of reducing the complete text of a guide specification into a database of values and brief descriptions is that some information is lost in the process. This challenge is dealt with in part by sufficiently narrowing the scope of this study as addressed above and also by carefully selecting what information is most critical.

Another challenge of creating a single database of fill material requirements from diverse sources is standardization of the language. Of particular interest in this regard are the terms used for describing the intended purposes of the fill materials being considered. A balance had to be found between preserving the specific language of a guide specification and entering data into the database in a usable and comparable form. For instance, the following terms found in the guide specifications of this study have meanings that overlap in some ways and connote differences in others:

1. "fill for buildings" and "fill for structures"
2. "fill for utilities" and "fill for trenches"

3. "base fill" and "bedding fill"
4. "select fill" and "controlled fill"

In this study, every effort was made to consistently use the same terminology in creating the database.

Some gradation requirements for fill materials found in guide specifications are very lengthy and highly detailed, especially for granular fill materials. In these cases, such as when several alternative gradations are specified or a gradation matrix of all possible gradation alternatives is presented, the most commonly used gradation requirements were entered into the database.

Some guide specifications require that a numerical value be specified in the contract specification for a particular fill material characteristic, but do not specify what value to use or even recommend one. Instances such as these are treated the same way as those in which the guide specifications say nothing at all about the value.

Sometimes one section of a guide specification will not give a fill material requirement because the requirement is given in more general terms in another section of the guide specification. If no cross-reference is provided, then determining whether or not the fill material requirement is specified elsewhere becomes a daunting task. In these instances, if the more general requirement could be found, then it was applied to the particular purpose being considered. If a more general requirement was not found, then it was assumed that the specification says nothing in this regard.

Choosing a Software Application

The first tangible step in the creation of the computer database was to choose an appropriate software application. Three software applications were examined for this purpose: Microsoft Word, Microsoft Excel, and Microsoft Access.

Microsoft Word and Excel

The initial database created for this study consisted of a relatively simple table in Microsoft Word. This approach was chosen initially because it could easily accommodate paragraph size text descriptions as necessary, which made it easier to preserve more of the language of the guide specification. This approach, however, had two flaws that prevented it from clearly showing trends in the data.

The first flaw was the result of the specific design used for the table – it did not draw the appropriate distinction between uses and types of fill materials. This is a critical distinction that had to made before useful conclusions could be drawn from the data. While this flaw could have been corrected, the second flaw was more fundamental and could not be solved without a change in software application.

The second flaw of the table in Microsoft Word was its rigidity, that is, it did not allow for efficient entry and storage of data and it did not allow the data to be sorted and rearranged with the level of flexibility needed. The possibility of using Microsoft Excel instead of Word was considered, but Excel did not add enough flexibility to the database and was therefore not used. However, Excel was utilized in this study for creating charts and graphs.

Microsoft Access

It was finally decided that a relational database such as Microsoft Access would be the best choice of software application for this study. The power of a relational database comes from the fact that it stores data in separate smaller tables instead of in one large table. This agency structure allows the data to be combined and compared with much greater flexibility than could be done with either Microsoft Word or Excel. A relational database also allows for more efficient data entry since any data that are repeated in multiple records has to be entered only once. Finally, Access encourages uniformity of data entry, which further enhances the comparability of the data. In contrast, records in Word may have individualities of format or language that prevent easy comparison. The next section explains these concepts in greater detail using specific examples from this study.

Design of the Database

Fill materials requirements were entered, stored, and examined using tables, queries, forms, and reports from Access and the plotting capability of Excel.

Tables

Tables are the fundamental building blocks of any relational database. Tables are composed of fields and records where raw data are stored in small groups. Records are stored in the rows of the table and field values are stored in the columns of the table. The fill materials database in this study is composed of the seven tables described below.

Agency

The Agencies table shown in Figure 3.1 has one field called "Agency" with a unique agency name in each row. Each name is entered into the table manually.

Purposes

The Purposes table shown in Figure 3.2 has one field called "Purpose" with a unique fill material purpose in each row. Each purpose is entered into the table manually.

Satisfactory Soil

The Satisfactory Soils table shown in Figure 3.3 has three fields called "satisfactory soil ID", "satisfactory soil", and "agency". In each row there is a unique alphanumeric ID, a unique satisfactory soil description, and the name of the agency that authored the description. The alphanumeric ID's were created solely for the purpose of this database. They consist of an abbreviation of the agency's name, a number, and an abbreviation of the fill material requirement category. For example, if three different descriptions of satisfactory soil are used by NASA, then the three associated ID's that would be used in this database would be nasa1s, nasa2s, and nasa3s. The creation of unique ID's is an important step in building a relational database as demonstrated later in this report.

For each record in the Satisfactory Soils table, data are entered manually into the description and ID fields. The agency name can selected from a drop down menu if the name has already been entered into the Agencies table.

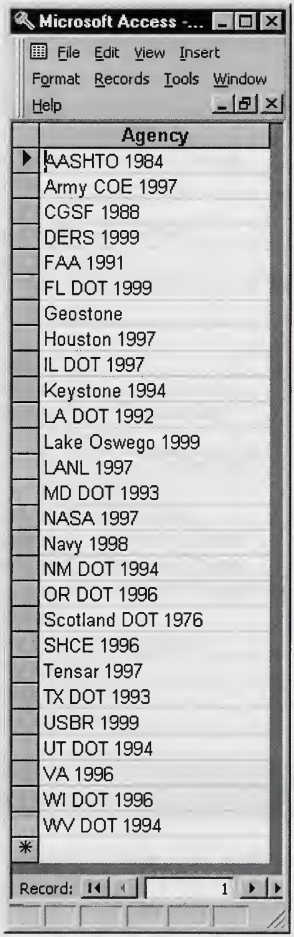


Figure 3.1 - Agencies table

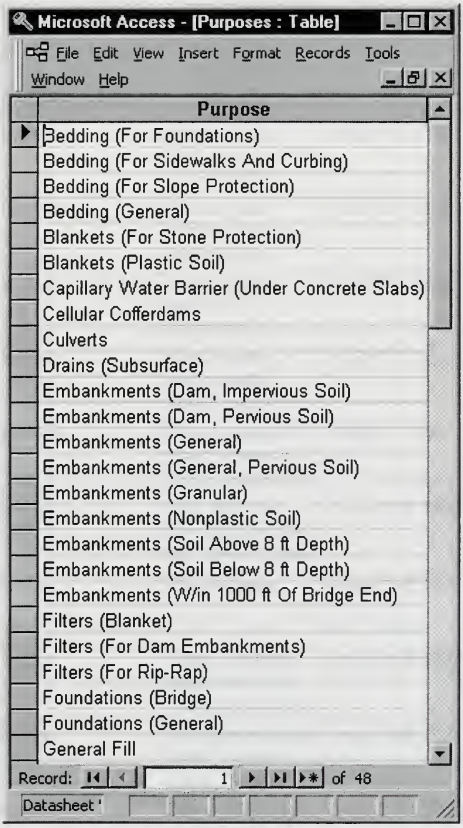


Figure 3.2 - Purposes table

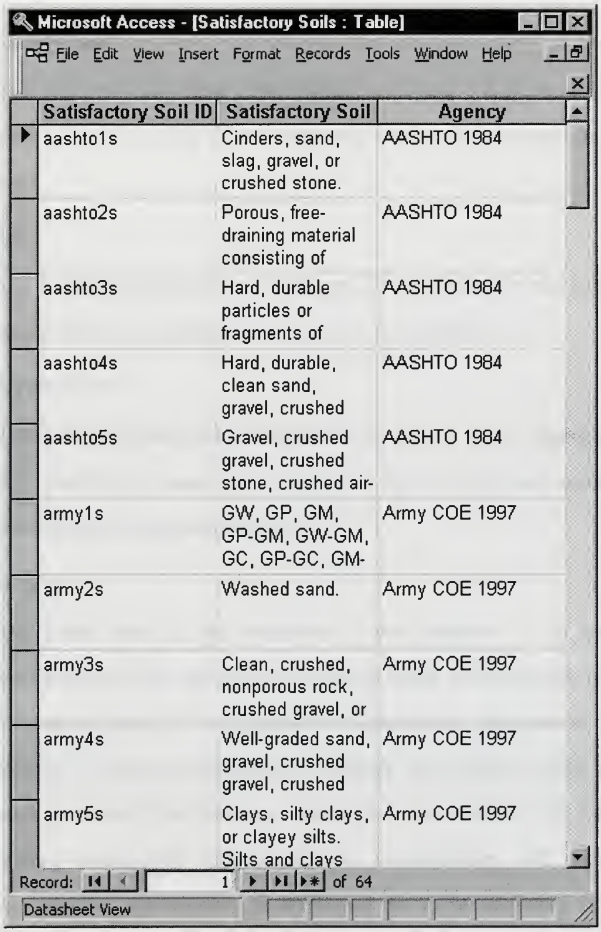


Figure 3.3 - Satisfactory soils table

Unsatisfactory Soil

The Unsatisfactory Soils table shown in Figure 3.4 is identical to the Satisfactory Soil table except that it contains a list of unique unsatisfactory soil descriptions.

Gradation

The Gradations table shown in Figure 3.5 is identical to the Satisfactory soils table except that it contains a list of unique soil gradations.

Other Requirements

The Other Requirements table shown in Figure 3.6 is identical to the Satisfactory Soils table except that it contains a list of unique soil requirements not included in any of the previous tables.

Main Table

The Main Table is the backbone of the database. It is where the information from all of the previously mentioned tables is merged into one larger table. As seen in Figure 3.7, it is composed of nine fields. Each row of the Main Table contains a unique combination of agency and purpose along with the corresponding material requirements. Each row also contains the IDs of the corresponding satisfactory soil description, unsatisfactory soil description, gradation, and other requirements. In addition to the six fields already mentioned, each row in the Main Table has fields for maximum particle size, maximum liquid limit, and maximum plasticity index that are called "particle size", "liquid limit", and "plasticity index", respectively. In each row, information in the first six fields

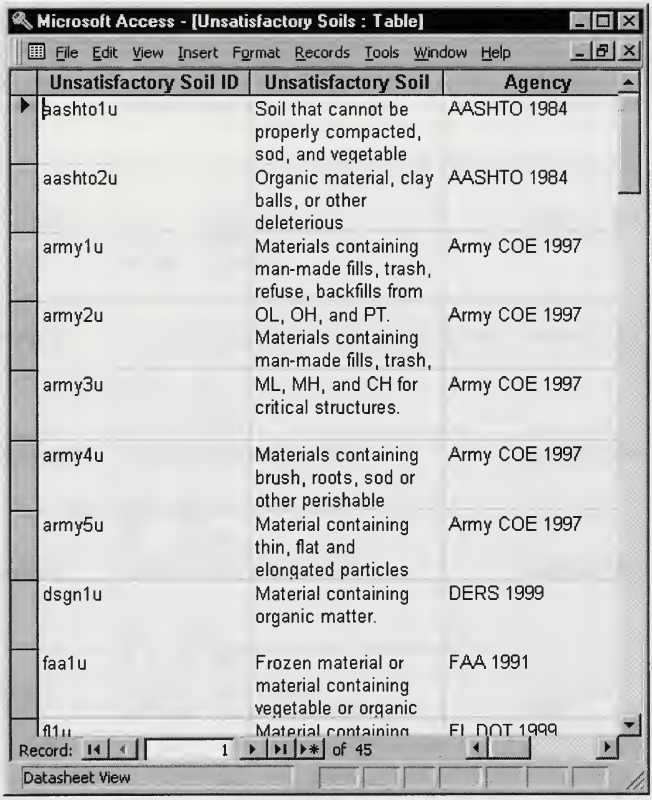


Figure 3.4 - Unsatisfactory soils table

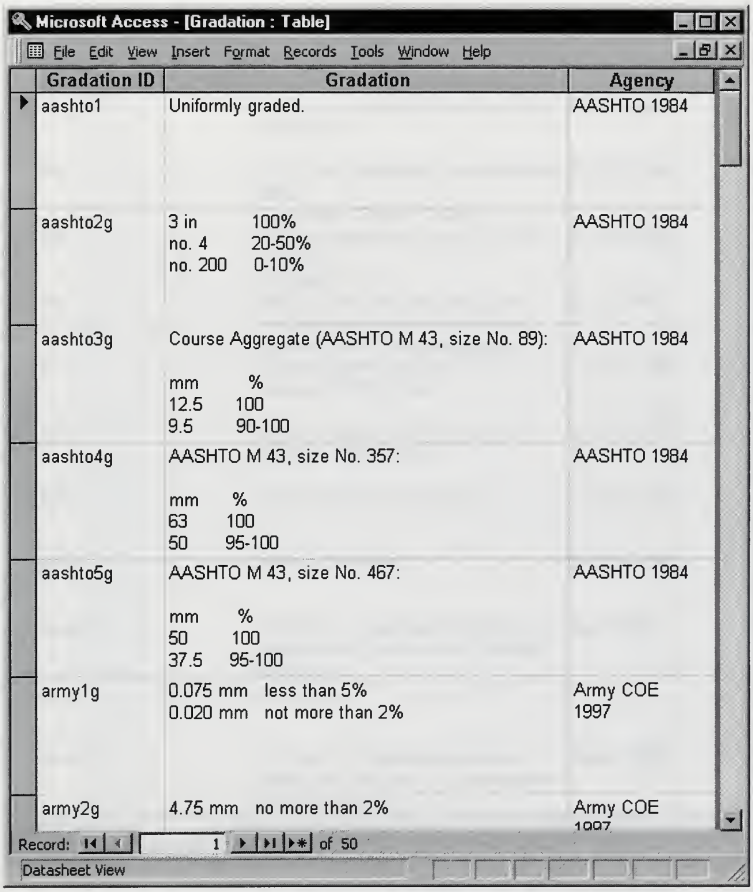


Figure 3.5 - Gradations table

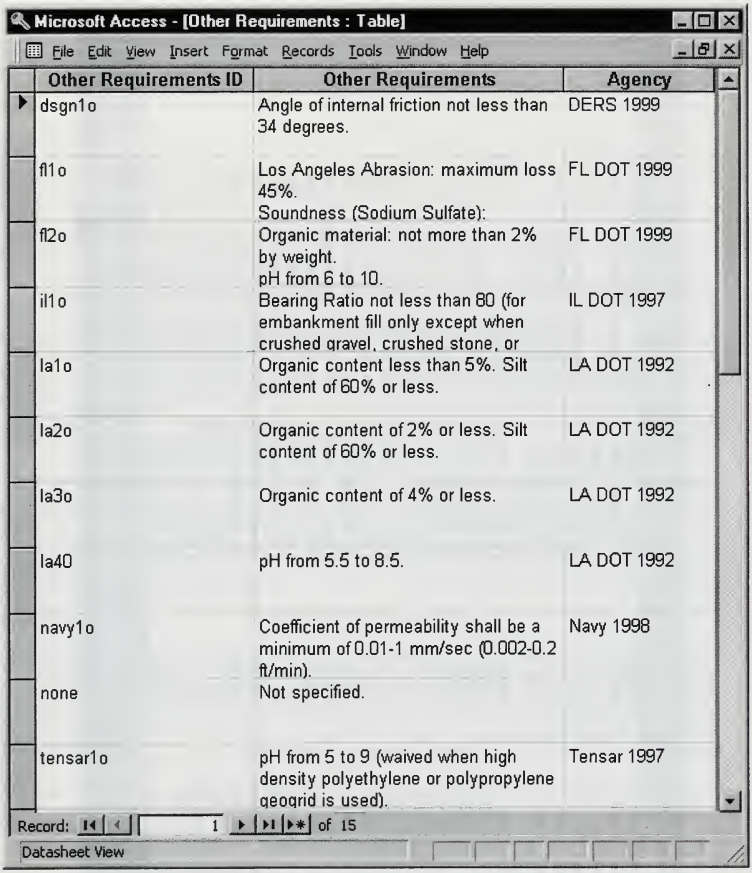
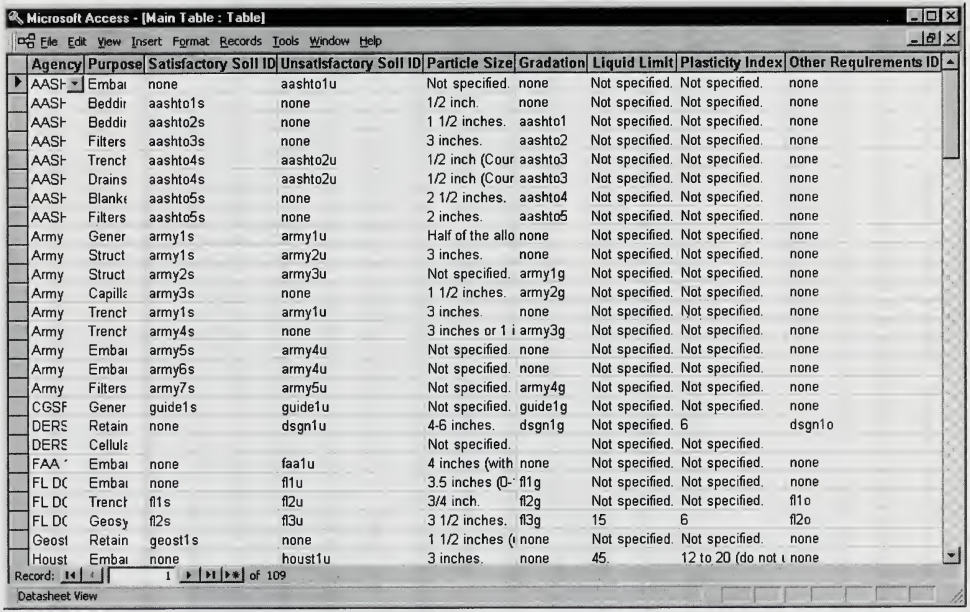


Figure 3.6 - Other requirements table



Microsoft Access - [Main Table : Table]

File Edit View Insert Format Records Tools Window Help

Agency	Purpose	Satisfactory Soil ID	Unsatisfactory Soil ID	Particle Size	Gradation	Liquid Limit	Plasticity Index	Other Requirements ID
AASH	Embai	none	aashto1u	Not specified.	none	Not specified.	Not specified.	none
AASH	Beddir	aashto1s	none	1/2 inch.	none	Not specified.	Not specified.	none
AASH	Beddir	aashto2s	none	1 1/2 inches.	aashto1	Not specified.	Not specified.	none
AASH	Filters	aashto3s	none	3 inches.	aashto2	Not specified.	Not specified.	none
AASH	Trencl	aashto4s	aashto2u	1/2 inch (Cour	aashto3	Not specified.	Not specified.	none
AASH	Drains	aashto4s	aashto2u	1/2 inch (Cour	aashto3	Not specified.	Not specified.	none
AASH	Blanke	aashto5s	none	2 1/2 inches.	aashto4	Not specified.	Not specified.	none
AASH	Filters	aashto5s	none	2 inches.	aashto5	Not specified.	Not specified.	none
Army	Gener	army1s	army1u	Half of the allo	none	Not specified.	Not specified.	none
Army	Struct	army1s	army2u	3 inches.	none	Not specified.	Not specified.	none
Army	Struct	army2s	army3u	Not specified.	army1g	Not specified.	Not specified.	none
Army	Capilla	army3s	none	1 1/2 inches.	army2g	Not specified.	Not specified.	none
Army	Trencl	army1s	army1u	3 inches.	none	Not specified.	Not specified.	none
Army	Trencl	army4s	none	3 inches or 1 i	army3g	Not specified.	Not specified.	none
Army	Embai	army5s	army4u	Not specified.	none	Not specified.	Not specified.	none
Army	Embai	army6s	army4u	Not specified.	none	Not specified.	Not specified.	none
Army	Filters	army7s	army5u	Not specified.	army4g	Not specified.	Not specified.	none
CGSF	Gener	guide1s	guide1u	Not specified.	guide1g	Not specified.	Not specified.	none
DERS	Retain	none	dsgn1u	4-6 inches.	dsgn1g	Not specified.	6	dsgn1o
DERS	Cellula			Not specified.		Not specified.	Not specified.	
FAA '	Embai	none	faa1u	4 inches (with	none	Not specified.	Not specified.	none
FL DC	Embai	none	fl1u	3.5 inches (0-'	fl1g	Not specified.	Not specified.	none
FL DC	Trencl	fl1s	fl2u	3/4 inch.	fl2g	Not specified.	Not specified.	fl1o
FL DC	Geosy	fl2s	fl3u	3 1/2 inches.	fl3g	15	6	fl2o
Geost	Retain	geost1s	none	1 1/2 inches (i	none	Not specified.	Not specified.	none
Houst	Embai	none	houst1u	3 inches.	none	45.	12 to 20 (do not i	none

Record: 1 of 109

Datasheet View

Figure 3.7 - Main table

mentioned above can be entered into the fields with the use of drop down menus (assuming the data have already been manually entered into the corresponding tables). In each of the latter three fields, the information is entered manually. The information in these latter three fields varied too widely in this study to warrant the creation of separate tables for these data.

Queries

Queries bring together information from different individual tables into a single table in a meaningful way. Although this may sound very similar to what the Main Table does, the difference is in what information is displayed. Queries match two or more records from different tables that have similar data in one of their fields and then display those two records as one new record with only the desired information shown. For example, in the Main Table there may be several records with gradation IDs that exactly match the gradation ID of a record in the Gradations table. By finding fields with matching data, a query can identify which records from these two tables are related, take only selected fields from each of these records, and string these selected fields together to create a new temporary record that is displayed in a query table. For example, a query could be used to create a new table that has only agency, purpose, and gradation as the column headings with the corresponding data shown in the rows of the table. The gradation IDs, which are not of interest, would not be displayed.

Figure 3.8 is a graphical representation of the tables and the relationships between tables that are used by queries to identify what records are related in the set of tables. All of the tables in the database are shown in this figure along with

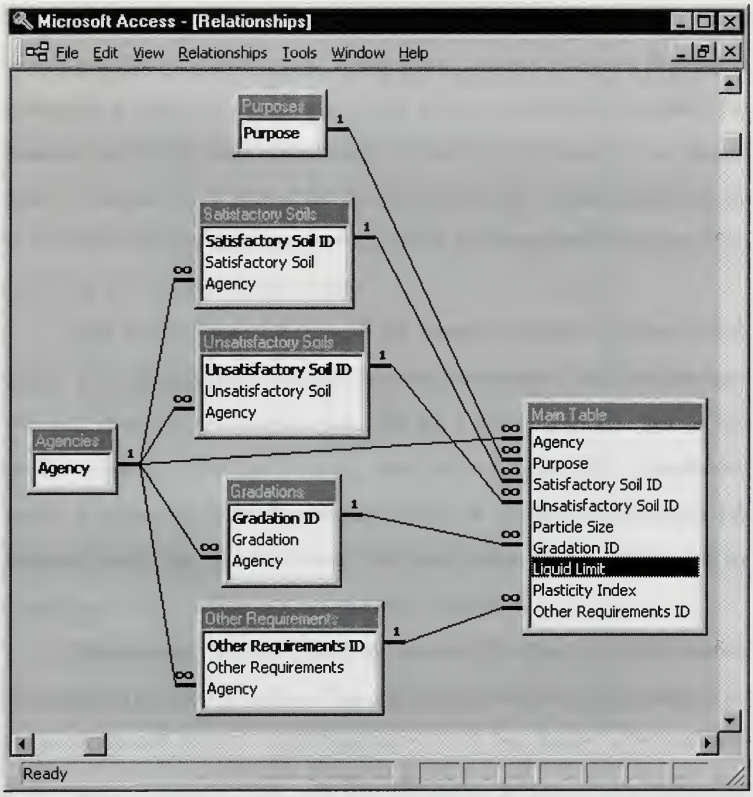


Figure 3.8 - Database relationships diagram

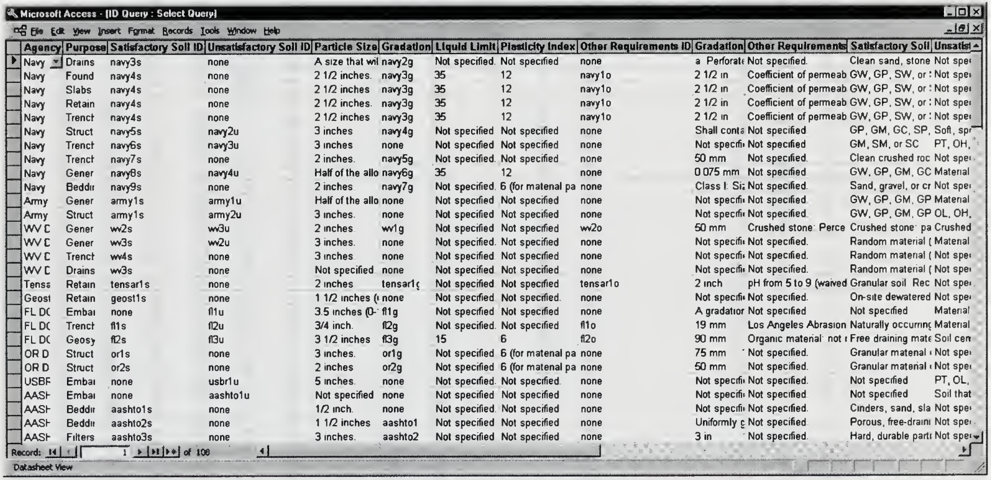
their field names introduced previously in this report. A field name that is shown in bold is called the "primary key" of that table. A primary key is a field that is guaranteed to contain a value that is unique to only one record in the table. For example, say that the value of a primary key field of a given record in one table is found in another record somewhere else in the database. In this example, it can be concluded that the latter record refers only to the former record since no other record has the same primary key value.

Each line in Figure 3.8 connects the common field that is present in both tables. The infinity symbol indicates that multiple records in that table can have identical values for the common field, but the 1 symbol indicates that no two records in that table can share the same value for the common field. In tables that contain a primary key field, the common field is the primary key field and a 1 is displayed next to the bold field name. The relationships shown in Figure 3.8 are examples of what is known as a one-to-many relationship.

The database that was created for this study has four predefined queries. These queries are used to gather information from the database in preparation for producing printed reports. Additional queries with any desired combination of fields can be created as well. The four predefined queries of the database are discussed below.

ID Query

The ID Query shown in Figure 3.9 looks very much like the Main Table except that both the descriptions and the IDs for the descriptions are displayed.



Microsoft Access - [ID Query : Select Query]

File Edit View Insert Format Records Tools Window Help

Agency	Purpose	Satisfactory Soil ID	Unsatisfactory Soil ID	Particle Size	Gradation	Liquid Limit	Plasticity Index	Other Requirements ID	Gradation	Other Requirements	Satisfactory Soil	Unsatisf
Navy	Drains	navy3s	none	A size that wil	navy2g	Not specified.	Not specified	none	a Perforat	Not specified.	Clean sand, stone	Not spe
Navy	Found	navy4s	none	2 1/2 inches.	navy3g	35	12	navy1o	2 1/2 in	Coefficient of permeab	GW, GP, SW, or :	Not spe
Navy	Slabs	navy4s	none	2 1/2 inches	navy3g	35	12	navy1o	2 1/2 in	Coefficient of permeab	GW, GP, SW, or :	Not spe
Navy	Retain	navy4s	none	2 1/2 inches.	navy3g	35	12	navy1o	2 1/2 in	Coefficient of permeab	GW, GP, SW, or :	Not spe
Navy	Trencl	navy4s	none	2 1/2 inches	navy3g	35	12	navy1o	2 1/2 in	Coefficient of permeab	GW, GP, SW, or :	Not spe
Navy	Struct	navy5s	navy2u	3 inches	navy4g	Not specified	Not specified	none	Shall conta	Not specified	GP, GM, GC, SP,	Soft, sp
Navy	Trencl	navy6s	navy3u	3 inches	none	Not specified	Not specified	none	Not specifi	Not specified	GM, SM, or SC	PT, OH,
Navy	Trencl	navy7s	none	2 inches.	navy5g	Not specified.	Not specified	none	50 mm	Not specified.	Clean crushed roc	Not spe
Navy	Gener	navy8s	navy4u	Half of the allo	navy6g	35	12	none	0.075 mm	Not specified	GW, GP, GM, GC	Material
Navy	Beddi	navy9s	none	2 inches.	navy7g	Not specified.	6 (for material pa	none	Class I: Si	Not specified.	Sand, gravel, or cr	Not spe
Army	Gener	army1s	army1u	Half of the allo	none	Not specified	Not specified	none	Not specifi	Not specified	GW, GP, GM, GP	Material
Army	Struct	army1s	army2u	3 inches.	none	Not specified	Not specified	none	Not specifi	Not specified	GW, GP, GM, GP	OL, OH,
WV D	Gener	wv2s	wv3u	2 inches	wv1g	Not specified	Not specified	wv2o	50 mm	Crushed stone: Perce	Crushed stone: pa	Crushed
WV D	Gener	wv3s	wv2u	3 inches.	none	Not specified.	Not specified	none	Not specifi	Not specified.	Random material (	Material
WV D	Trencl	wv4s	none	3 inches	none	Not specified	Not specified	none	Not specifi	Not specified.	Random material (	Not spe
WV D	Drains	wv3s	none	Not specified	none	Not specified	Not specified	none	Not specifi	Not specified.	Random material (	Not spe
Tensa	Retain	tensar1s	none	2 inches	tensar1g	Not specified	Not specified	tensar1o	2 inch	pH from 5 to 9 (waived	Granular soil. Rec	Not spe
Geost	Retain	geost1s	none	1 1/2 inches (	none	Not specified	Not specified.	none	Not specifi	Not specified.	On-site dewatered	Not spe
FL DC	Embai	none	fl1u	3.5 inches (0-	fl1g	Not specified	Not specified	none	A gradatior	Not specified	Not specified	Material
FL DC	Trencl	fl1s	fl2u	3/4 inch.	fl2g	Not specified.	Not specified	fl1o	19 mm	Los Angeles Abrasion	Naturally occurring	Material
FL DC	Geosy	fl2s	fl3u	3 1/2 inches	fl3g	15	6	fl2o	90 mm	Organic material: not	Free draining mate	Soil cen
OR D	Struct	or1s	none	3 inches.	or1g	Not specified	6 (for material pa	none	75 mm	Not specified.	Granular material	Not spe
OR D	Struct	or2s	none	2 inches	or2g	Not specified	6 (for material pa	none	50 mm	Not specified.	Granular material	Not spe
USBF	Embai	none	usbr1u	5 inches.	none	Not specified.	Not specified.	none	Not specifi	Not specified.	Not specified	PT, OL,
AASH	Embai	none	aashto1u	Not specified	none	Not specified	Not specified	none	Not specifi	Not specified	Not specified	Soil that
AASH	Beddi	aashto1s	none	1/2 inch.	none	Not specified.	Not specified	none	Not specifi	Not specified.	Cinders, sand, sla	Not spe
AASH	Beddi	aashto2s	none	1 1/2 inches	aashto1	Not specified	Not specified	none	Uniformly g	Not specified	Porous, free-draini	Not spe
AASH	Filters	aashto3s	none	3 inches.	aashto2	Not specified	Not specified	none	3 in	Not specified.	Hard, durable parti	Not spe

Record: 1 of 108

Datasheet View

Figure 3.9 - ID query

This query is used to compile a list of records that contain all of the information in the entire database.

Description Query

The Description Query shown in Figure 3.10 also looks like the Main Table except that it displays descriptions instead of IDs. This query is used to compile a list of records that contain all of the information in the entire database except the IDs.

Particle Size Query

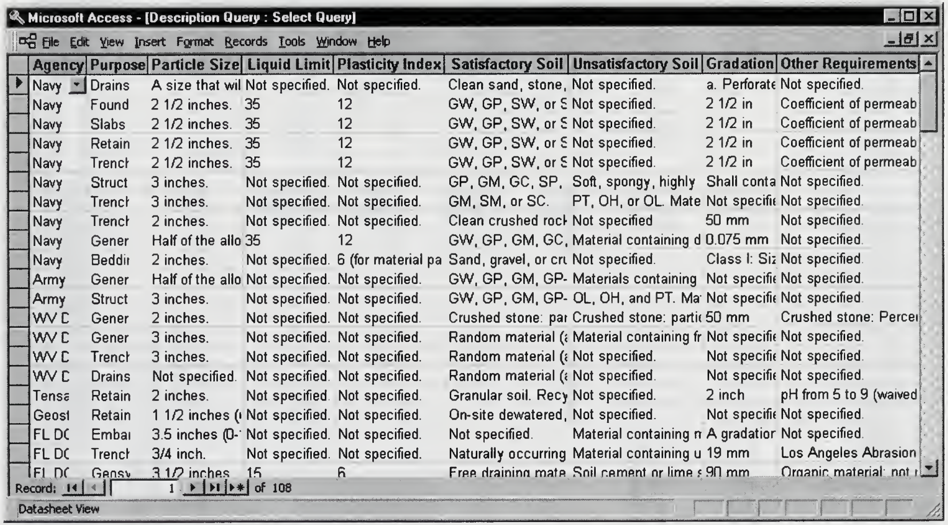
The Particle Size Query shown in Figure 3.11 is used to display records that show agency, purpose, and maximum particle size only.

Atterberg Limits Query

The Atterberg Limits Query shown in Figure 3.12 is used to display records that show agency, purpose, liquid limit, and plasticity index only.

Forms

Both tables and the results of queries can be transformed into forms to aid with data entry and display. A form can be thought of as a table with only one row displayed at a time. Since a form displays only one record at a time, the fields can be rearranged and resized on the screen in a way that best shows the data that they contain. The database that was created for this study has six predefined forms. Additional forms with any desired combination of fields can be created as well. The six predefined forms of the database are introduced next.



Microsoft Access - [Description Query : Select Query]

File Edit View Insert Format Records Tools Window Help

Agency	Purpose	Particle Size	Liquid Limit	Plasticity Index	Satisfactory Soil	Unsatisfactory Soil	Gradation	Other Requirements
Navy	Drains	A size that wil	Not specified.	Not specified.	Clean sand, stone,	Not specified.	a. Perforate	Not specified.
Navy	Found	2 1/2 inches.	35	12	GW, GP, SW, or S	Not specified.	2 1/2 in	Coefficient of permeab
Navy	Slabs	2 1/2 inches.	35	12	GW, GP, SW, or S	Not specified.	2 1/2 in	Coefficient of permeab
Navy	Retain	2 1/2 inches.	35	12	GW, GP, SW, or S	Not specified.	2 1/2 in	Coefficient of permeab
Navy	Trench	2 1/2 inches.	35	12	GW, GP, SW, or S	Not specified.	2 1/2 in	Coefficient of permeab
Navy	Struct	3 inches.	Not specified.	Not specified.	GP, GM, GC, SP,	Soft, spongy, highly	Shall conta	Not specified.
Navy	Trench	3 inches.	Not specified.	Not specified.	GM, SM, or SC.	PT, OH, or OL. Mate	Not specifie	Not specified.
Navy	Trench	2 inches.	Not specified.	Not specified.	Clean crushed rock	Not specified	50 mm	Not specified.
Navy	Gener	Half of the allo	35	12	GW, GP, GM, GC,	Material containing d	0.075 mm	Not specified.
Navy	Beddi	2 inches.	Not specified.	6 (for material pa	Sand, gravel, or cru	Not specified.	Class I: Siz	Not specified.
Army	Gener	Half of the allo	Not specified.	Not specified.	GW, GP, GM, GP-	Materials containing	Not specifie	Not specified.
Army	Struct	3 inches.	Not specified.	Not specified.	GW, GP, GM, GP-	OL, OH, and PT. Ma	Not specifie	Not specified.
WV D	Gener	2 inches.	Not specified.	Not specified.	Crushed stone: par	Crushed stone: partic	50 mm	Crushed stone: Percei
WV D	Gener	3 inches.	Not specified.	Not specified.	Random material (a	Material containing fr	Not specifie	Not specified.
WV D	Trench	3 inches.	Not specified.	Not specified.	Random material (a	Not specified.	Not specifie	Not specified.
WV D	Drains	Not specified.	Not specified.	Not specified.	Random material (a	Not specified.	Not specifie	Not specified.
Tensa	Retain	2 inches.	Not specified.	Not specified.	Granular soil. Recy	Not specified.	2 inch	pH from 5 to 9 (waived
Geost	Retain	1 1/2 inches (i	Not specified.	Not specified.	On-site dewatered,	Not specified.	Not specifie	Not specified.
FL DO	Embai	3.5 inches (0-'	Not specified.	Not specified.	Not specified.	Material containing n	A gradatior	Not specified.
FL DO	Trench	3/4 inch.	Not specified.	Not specified.	Naturally occurring	Material containing u	19 mm	Los Angeles Abrasion
FL DO	Geosy	3 1/2 inches	15	6	Free draining mate	Soil cement or lime s	90 mm	Organic material: not r

Record: 1 of 108

Datasheet View

Figure 3.10 - Description query

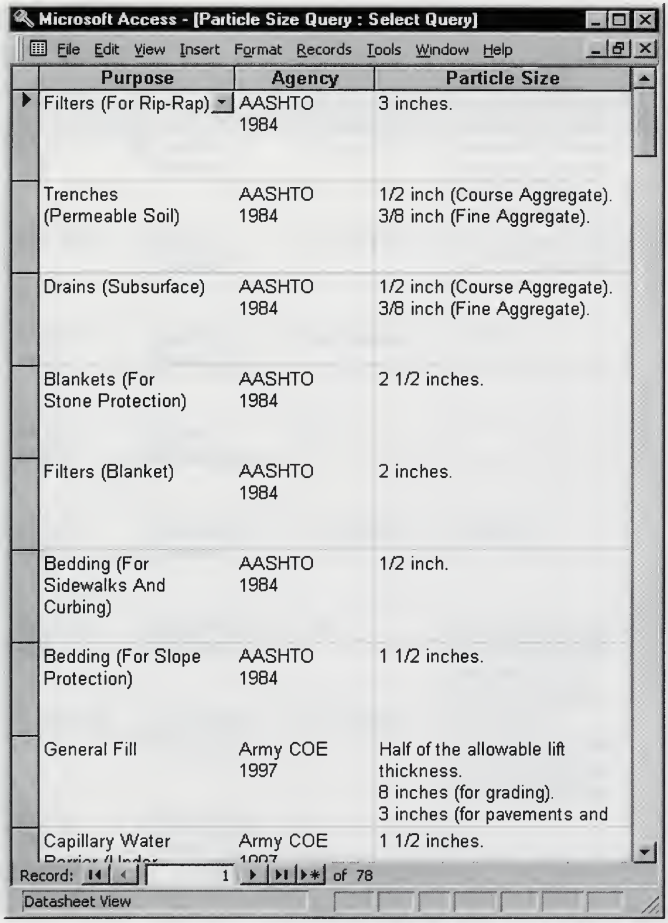


Figure 3.11 - Particle size query

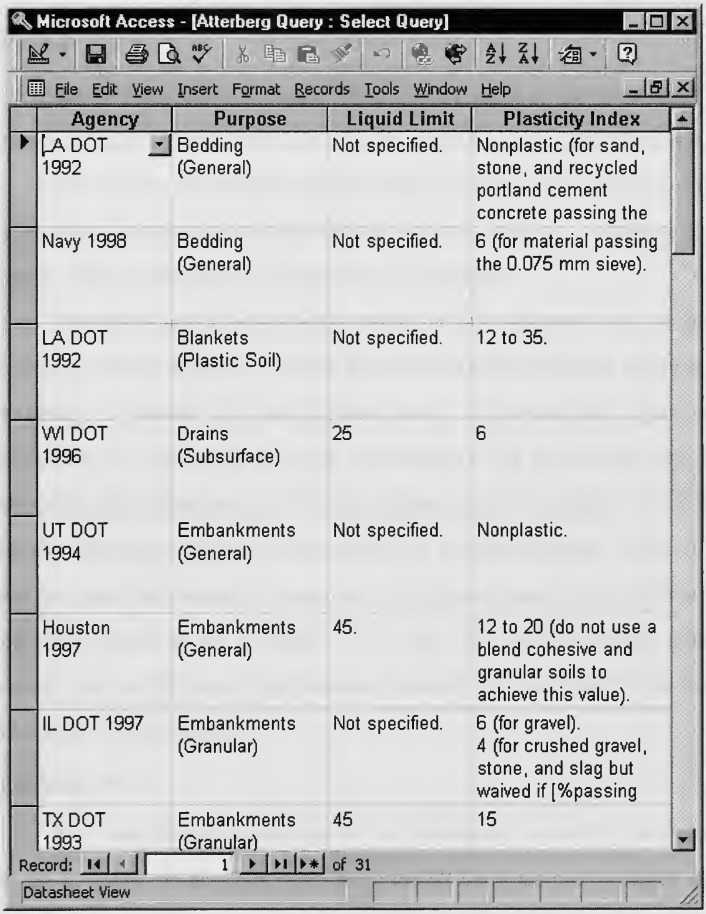


Figure 3.12 - Atterberg query

ID Form

The ID Form shown in Figure 3.13 is based directly on the ID Query. The ID Form contains the same fields and records as the ID Query. This form is used in conjunction with the Agencies table, Purposes table, and editor forms, which are explained below, to enter new records into the database. Following is an example of how a new record is entered into the database.

First, the name of the agency is entered into the Agencies table, unless it has been previously entered. Next, the purpose of the fill material as specified by the agency is entered into the Purposes table. Following this, qualitative descriptions of satisfactory soil and unsatisfactory soil are entered into the appropriate editor forms and new IDs are assigned to each description. Gradation data and other requirements data are entered in a similar fashion. After all of these data have been entered as described, they become available for selection via drop down menus in the ID Form. The only data that are directly entered manually into the ID Form is the maximum particle size, maximum liquid limit, and maximum plasticity index.

Description Form

The Description Form shown in 3.14 is identical to the ID Form except that the ID fields are not displayed. Since the ID fields are not displayed, drop down menus are not available for selecting different descriptions for satisfactory soil and other similar fields. Hence, this form is used only for viewing records when IDs are not important to the user and the user.

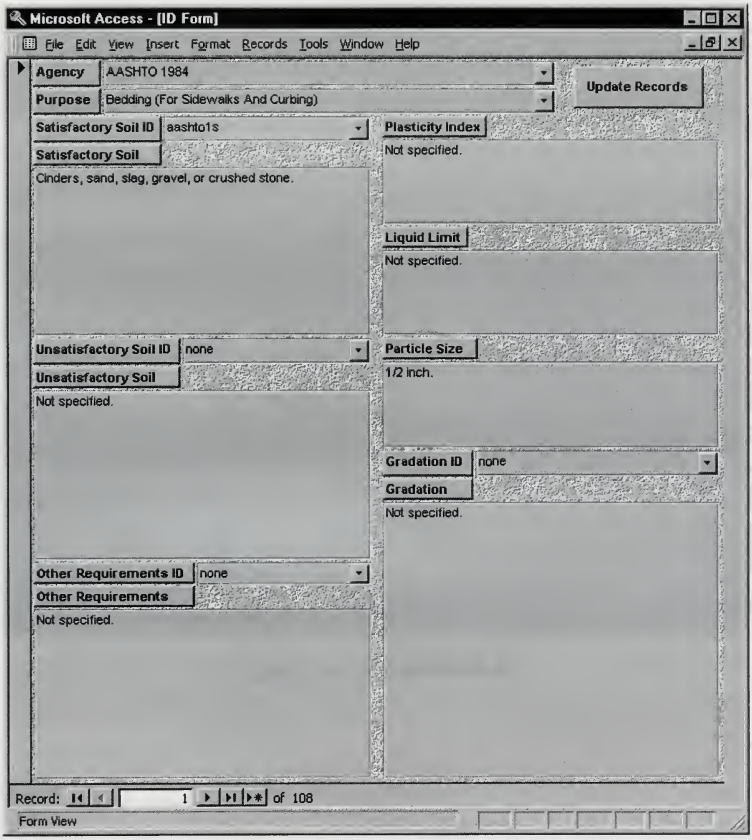


Figure 3.13 - ID form

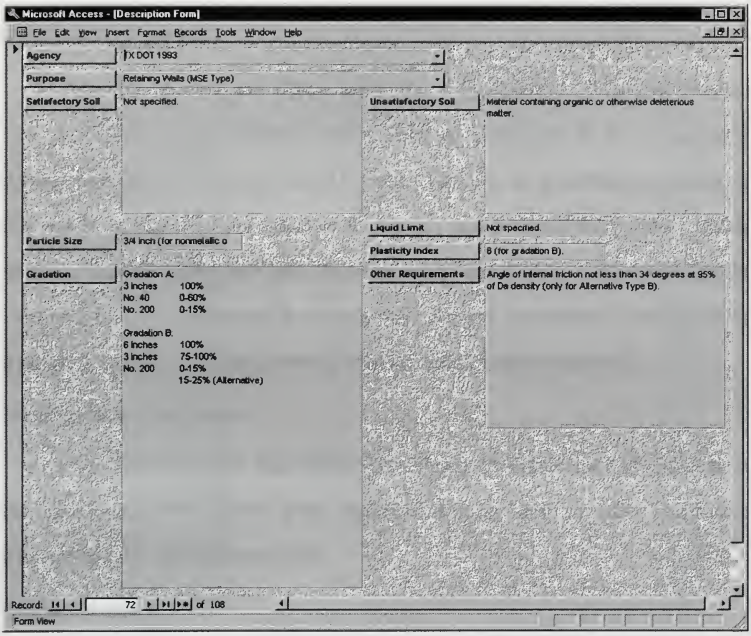


Figure 3.14 - Description form

Satisfactory Soil Editor

The Satisfactory Soil Editor form shown in Figure 3.15 is used to enter new descriptions of satisfactory soils. First, an alphanumeric ID is manually entered into the "Satisfactory Soil ID" field. This ID, as described previously in this report, is based on the name of the agency and a sequential number, which depends on how many previous descriptions of satisfactory soils have already been entered into the database for the agency. Second, a qualitative description of a satisfactory soil is manually entered into the field "Satisfactory Soil".

Unsatisfactory Soil Editor

The Unsatisfactory Soil Editor form shown in Figure 3.16 is identical to the Satisfactory Soil Editor form except that it is used to enter qualitative descriptions for unsatisfactory soils.

Gradation Editor

The Gradation Editor form shown in Figure 3.17 is identical to the Satisfactory Soil Editor form except that it is used to enter gradations in the form of sieve sizes and percent passing.

Other Requirements Editor

The Other Requirements Editor form shown in Figure 3.18 is identical to the Satisfactory Soil Editor form, except that it is used to enter other fill material requirements not covered elsewhere in the database. For example, a guide specification may stipulate pH or percentage of organic content.

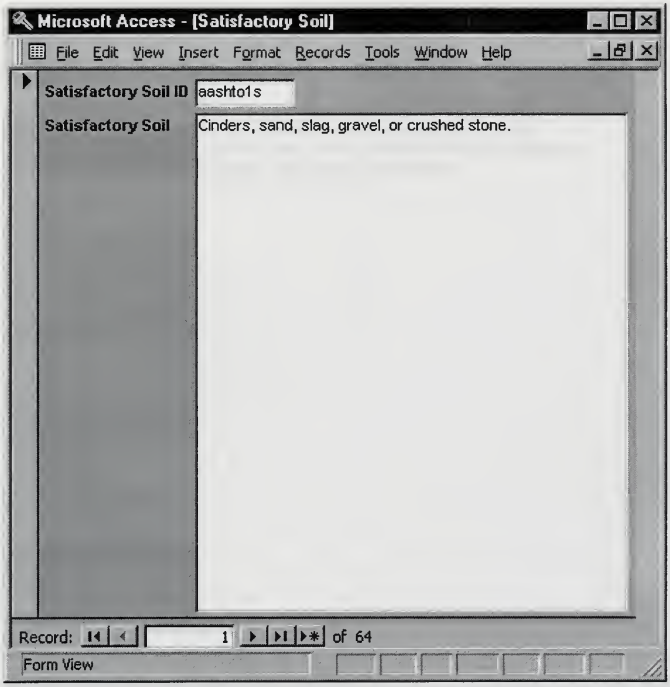


Figure 3.15 - Satisfactory soil editor form

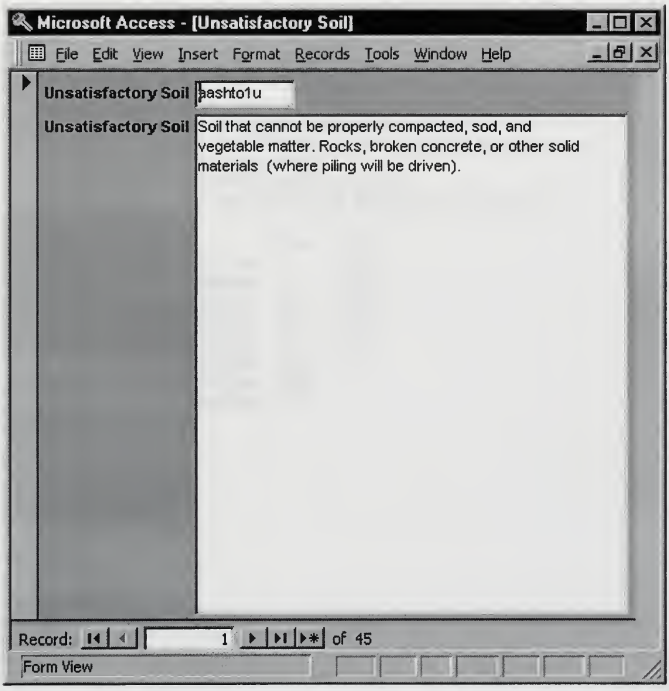


Figure 3.16 - Unsatisfactory soil editor form

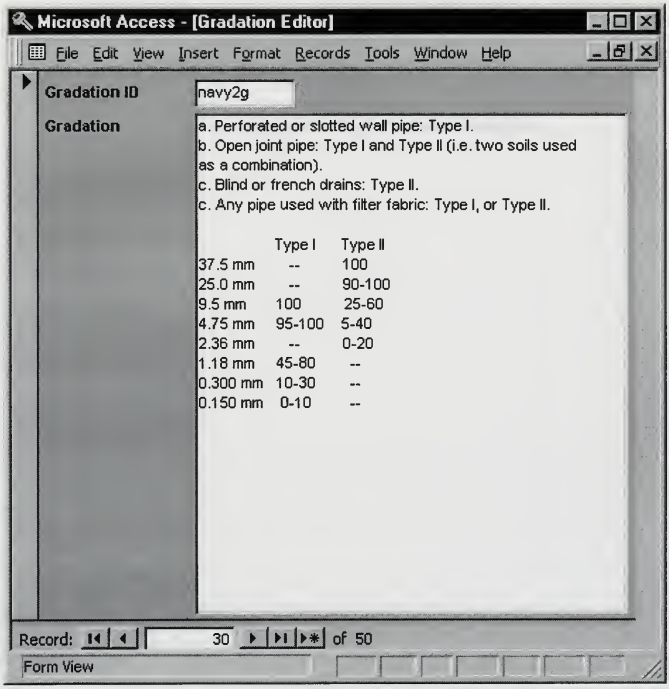


Figure 3.17 - Gradation editor form

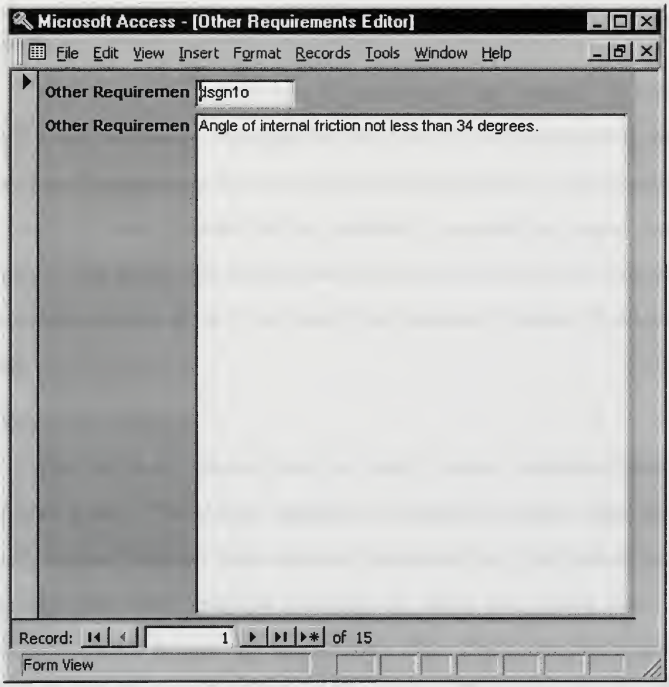


Figure 3.18 - Other requirements editor form

Reports

Both tables and queries can be transformed into reports. A report is simply a way of visually organizing the data found in the corresponding table or query into an arrangement that is easier to read and understand. The complete set of reports that was generated for the database is discussed in greater detail in Chapter 4. The reports generated by the database are one of the two ways used in this study to examine the data and identify the presence or absence of patterns and trends.

Plots

The data in the database were also used to create a number of plots with Microsoft Excel. The plotting capability of Microsoft Access cannot be used directly because database fields that hold numerical data (like particle size and Atterberg limits) were formatted as general text rather than number fields. This decision was made because the data for some of the fields were best represented with a text description rather than a single number. This is one area of potential improvement for this database. Ideally, all numbers in the database should be stored in numerical fields so that Access can generate the plots directly.

To generate a plot, data were first exported to an Excel spreadsheet as a table. Once in the spreadsheet, the textual data were "trimmed" away from the numerical values leaving a table of numbers with row and column headings as appropriate. The table of numerical values was then transformed into a graph

using the plotting ("charting") capabilities of Excel. The complete set of plots generated for this study is discussed in greater detail in Chapter 4.

Chapter 4: Trends in Current Practice and Further Recommendations

Once the database was created, it was used to examine possible patterns and trends in the requirements of various agencies. The results of this examination are presented in this chapter. The examination of fill requirements is presented as follows. First, a broad overview of all the data is presented. Next, maximum particle size requirements and Atterberg limit requirements stipulated for fill materials are examined. Descriptions for what are considered satisfactory and unsatisfactory fill materials are then presented. Following this, the specific gradation requirements for fill materials are introduced along with any other requirements for fill materials not already covered. Finally, recommendations for writing future guide specifications are made based on these evaluations.

Fill Requirements: All Requirements

Appendix A presents a tabular listing of all of the fill material requirements that were collected in this study. The table is sorted first by the purpose of the fill material and then by the name of the agency that authored the guide specification.

Fill Requirements: Maximum Particle Size

All of the maximum particle size requirements stipulated for fill materials in the database are plotted in Figure 4.1. The data in this figure are sorted according to the smallest maximum particle size specified by an agency for fill materials regardless of use. Each location along the horizontal axis corresponds

Figure 4.1 - Maximum particle size sorted by agency and purpose

to a specific purpose for the fill material and the agency issuing the guide specification. When an agency specifies more than one value for the purpose in question, the additional values are shown above the smallest size specified. Figure 4.2 shows the same data to an expanded scale that excludes sizes that are 12 inches or greater in order to provide more detail at the lower end of the scale of particle sizes. Nearly all of the maximum particle sizes specified are four inches or less. Three inches appears to be one of the most commonly specified maximum sizes.

Figures 4.3 and 4.4 show the same data presented in the previous two figures sorted by purpose of fill material; Figure 4.3 shows all maximum sizes, Figure 4.4 shows only maximum sizes less than 12 inches. The maximum particle sizes specified for fill materials to be used in embankments have both the greatest absolute range of values and greatest number of different values specified. A total of 11 different sizes ranging from 1 inch to 10 feet are specified for general embankments alone. Figures 4.5 and 4.6 show the same data as the previous four figures but grouped and sorted by the general category of purpose of fill material. When all types of embankments are considered, a total of 13 different maximum particle sizes were observed in the 27 guide specifications studied.

After embankments, the applications with the next greatest number of different values specified for maximum particle size are fill materials for retaining walls and fill materials for trenches. Seven values of maximum particle size (from less than one inch to six inches) are specified for fill materials for retaining

Figure 4.2 - Maximum particle size < 12 in sorted by agency and purpose

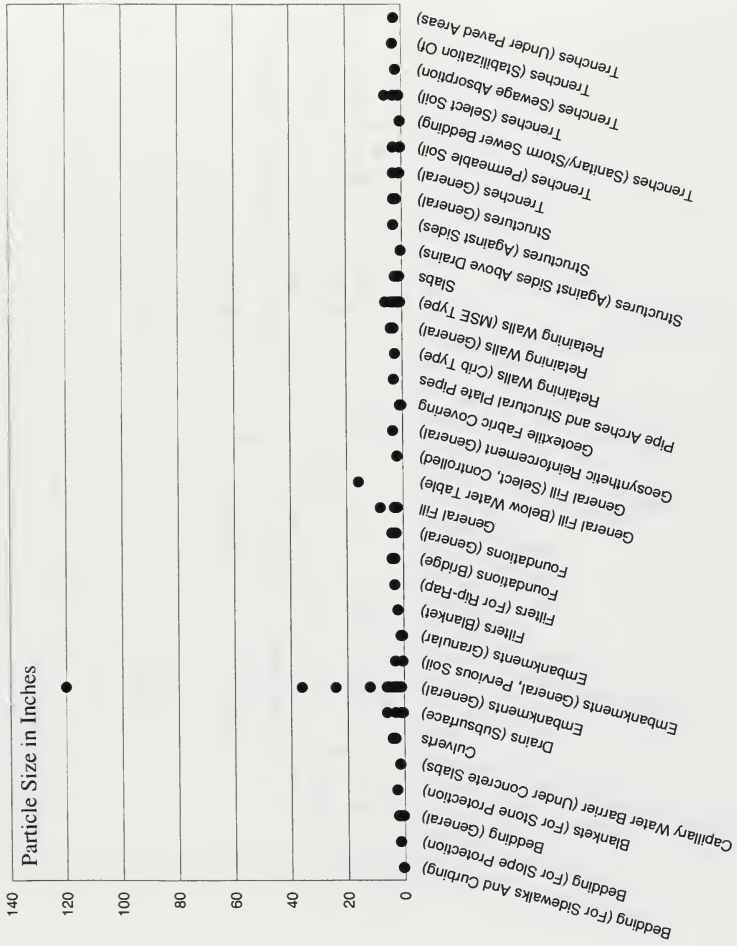


Figure 4.3 - Maximum particle size sorted by purpose

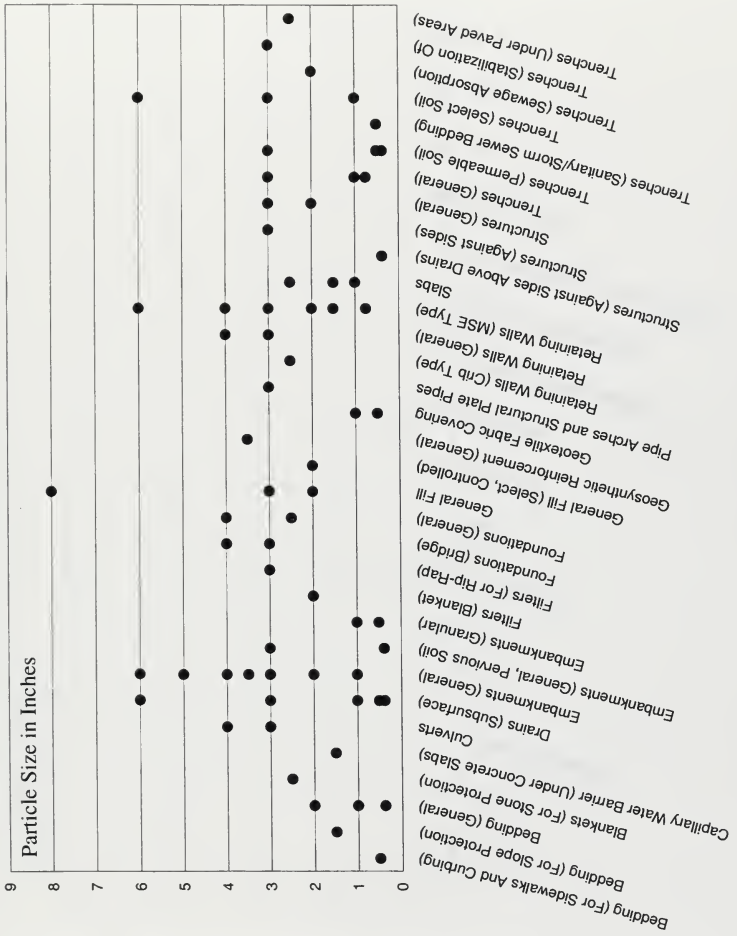


Figure 4.4 - Maximum particle size < 12 in sorted by purpose

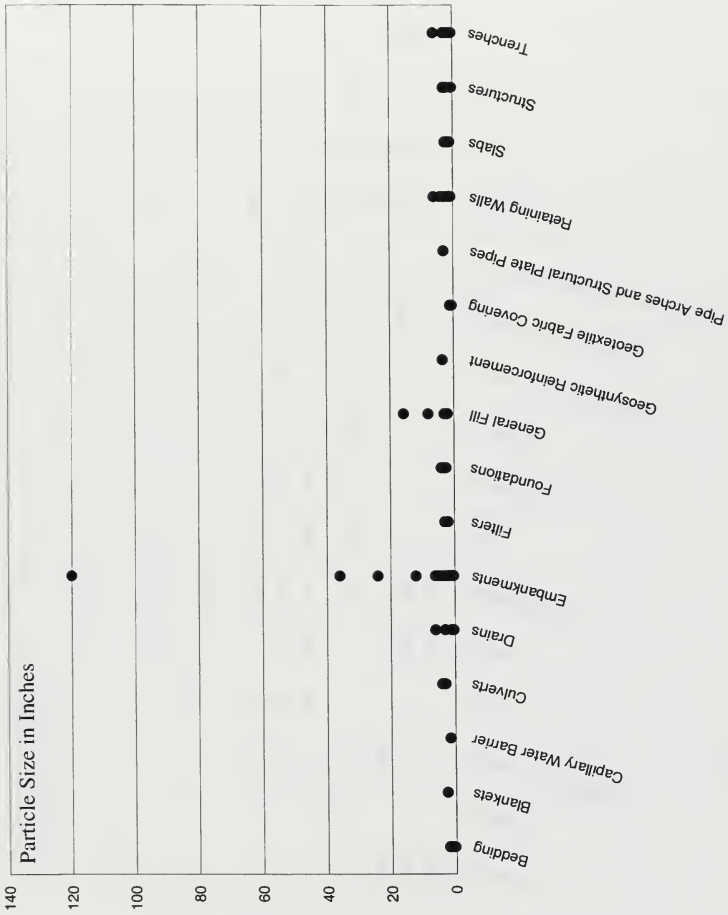


Figure 4.5 - Maximum particle size sorted by major purpose

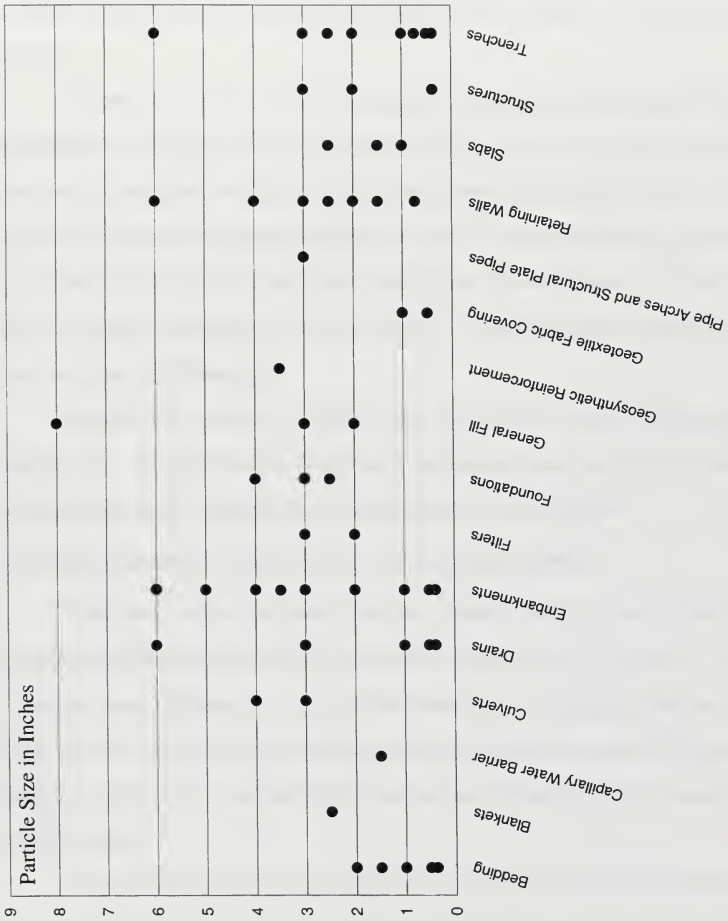


Figure 4.6 - Maximum particle size < 12 in sorted by major purpose

walls, and eight values (from less than one inch to six inches) are specified for trenches.

Figures 4.7 and 4.8 show the range of maximum particle size values stipulated by each agency. The prominence of the three inch maximum particle size can be seen here as well. It is the most commonly specified particle size among the agencies and purposes studied. Of the 27 guide specifications studied, only three did not specify a maximum particle size for any purpose. Of the 24 that did specify maximum particle size values, 14 specified three inches for at least one class of fill material.

Appendix B presents a tabular listing of all of the values of maximum particle size. This table also includes any supplemental comments that the guide specifications contain regarding the maximum particle size specified.

Fill Requirements: Liquid Limit and Plasticity Index

Maximum values for liquid limit and plasticity index given by the 27 guide specifications studied are both presented in Figures 4.9, 4.10, and 4.11. The values are sorted differently in each of the three figures. Multiple values in the same vertical column in the plots indicate that more than one value for the liquid limit or plasticity index was specified in that instance depending on the purpose of the fill material.

From these plots, it can be seen that nearly all of the maximum plasticity indices specified are 20 or less. Twelve of the 27 guide specifications specify plasticity index for at least one case. Of those twelve guide specifications, only two specify values greater than 20. In Figure 4.10, seven different values for

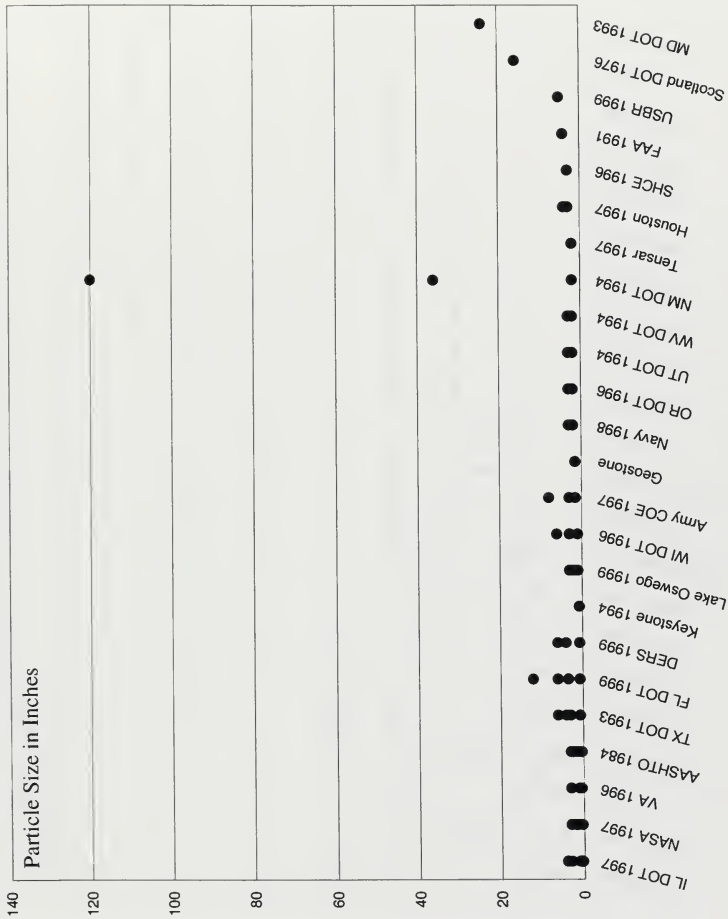


Figure 4.7 - Maximum particle size sorted by agency

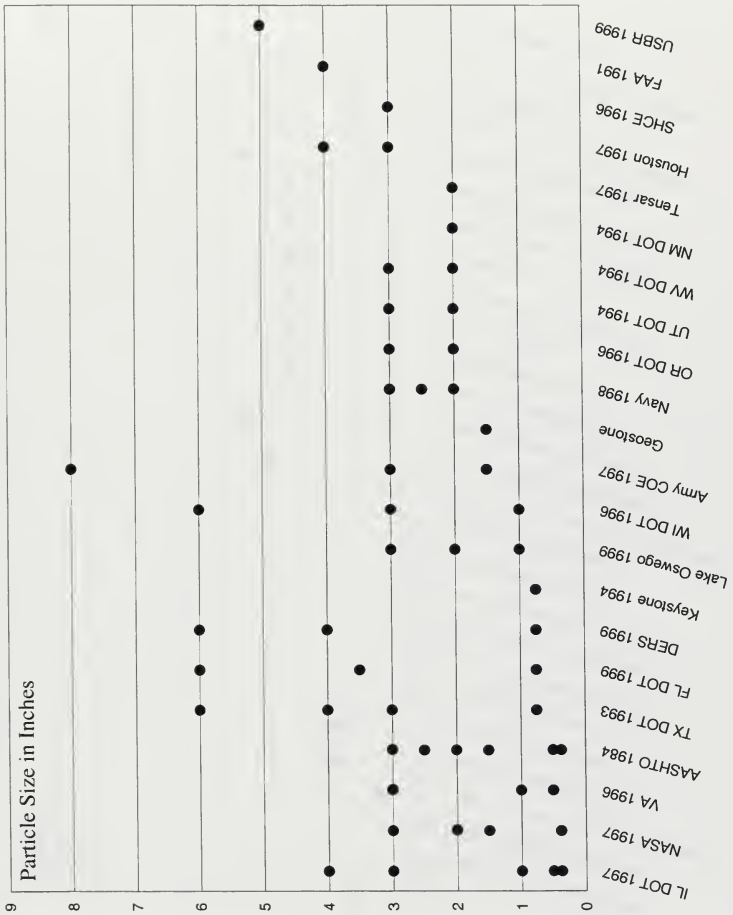


Figure 4.8 - Maximum particle size < 12 in sorted by agency

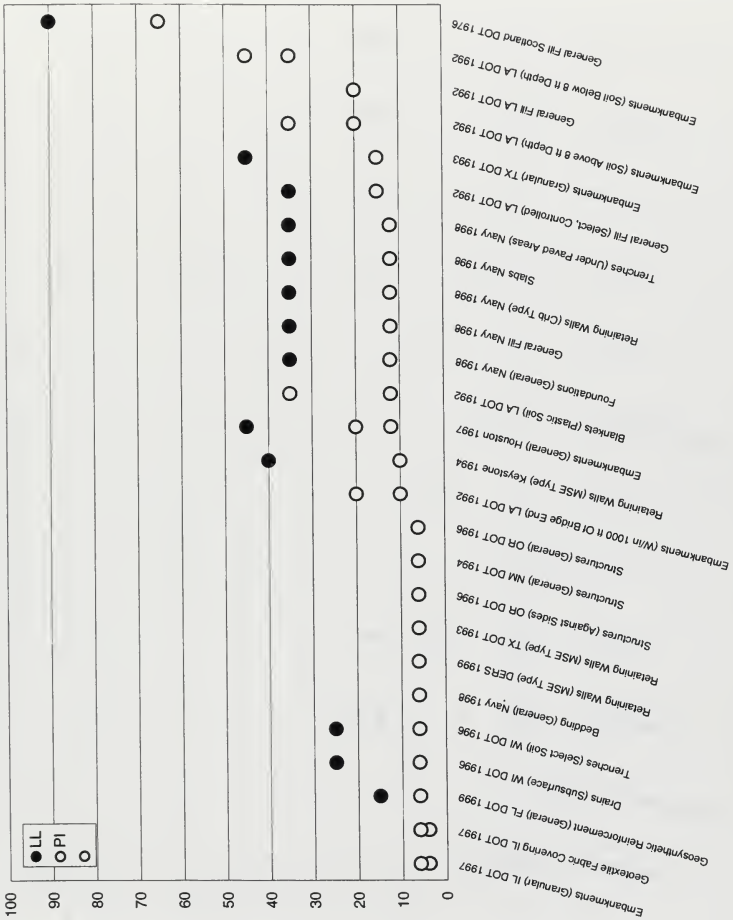


Figure 4.9 - Atterberg limits sorted by purpose and agency

Figure 4.10 - Atterberg limits sorted by major purpose

Figure 4.11 - Atterberg limits sorted by agency

plasticity index, the most of any category in this figure, are given for embankments. In Figure 4.11, five different values for plasticity index, the most of any category in this figure, are given by the Louisiana DOT.

Maximum liquid limit values range from 15 to 45 with one outlying value at 90. The most commonly specified value for liquid limit appears to be 35.

Appendix C presents a tabular listing of all of the values of maximum liquid limit and maximum plasticity index. This table also includes any supplemental comments that the guide specifications contain regarding the Atterberg limits specified.

Fill Requirements: Description of Satisfactory Soil

Table 4.1 is a summary of all the different terms that were encountered in the qualitative descriptions of satisfactory fill materials in the guide specifications. This list contains the basic nouns and adjectives used to describe satisfactory fill materials. Sand and gravel were among the most common terms encountered.

Appendix D lists the full qualitative descriptions of satisfactory fill materials contained in the various guide specifications. The table is arranged in alphabetical order by agency name.

Fill Requirements: Description of Unsatisfactory Soil

Table 4.2 is a summary of all the different terms that were encountered in the qualitative descriptions of unsatisfactory fill materials in the guide specifications. This list contains the basic nouns and adjectives used to describe

Table 4.1 - Satisfactory Fill Material Basic Terms

Material from, containing, or characterized as:		
aggregate (crushed)	angular	blow (fine desert)
broken	caliche	CH
chats	cinders	cinders (volcanic)
CL	clam shell	clay
clay (expanded)	clay (sandy)	clay (silty)
clean	CL-ML	cohesionless
compactible	concrete (crushed)	concrete (lean)
concrete (recycled)	concrete sand	concrete sand (crushed)
coral	crushed	dewatered
durable	earth	fragmented
free draining	GC	GM
GM-GC	GP	GP-GC
GP-GM	graded	granular
granulated	gravel	gravel (crushed)
gravel (natural)	gravel (pit run)	gravel (screened)
gravel (uncrushed)	gravel-sand mixture	GW
GW-GM	hard	impermeable
imported	inert	loam
MH	minerals (broken, fragmented)	ML
native excavated	naturally occurring	noncohesive
nonporous	novaculite	porous
random	reef shell	rock
rock (crushed)	rock (natural)	rock (round)
rock (uncrushed)	rock fill	round
sand	sand (coarse)	sand (construction/demo debris)
sand (fine beach)	sand (natural)	sandstone (crushed)
SC	screened	shale
shale (hard)	shale (soft)	shell
shell (crushed)	silt	silt (clayey)
site excavated	slag	slag (air cooled blast-furnace)
slag (crushed)	slag (wet bottom boiler)	slag sand
slag sand (granulated)	SM	soil
soil (natural)	soil (site excavated)	SP
SP-SC	SP-SM	stone
stone (angular)	stone (crushed)	stone sand
stone screenings	stream deposited	strong
SW	SW-SC	SW-SM
tough	uniformly graded	washed
well graded		

Table 4.2 - Unsatisfactory Fill Material Basic Terms

Material from, containing, or characterized as:		
adherent coatings	aggregates	alkali
backfills (from previous construction)	backfills (uncompacted)	bogs
broken concrete	brush	CH
chemical contamination	clay balls	clay clods
clay lumps	CL-ML	clods
compacted (cannot be)	construction debris	contamination
damaging to pipe	debris	decaying
decomposing	deleterious	diatomaceous
dirt	extraneous	fills (man-made)
foreign	foundation (not usable for)	friable
frozen	humus	hydrocarbons
ice	inorganic	lenses (soil)
limbs	lime stabilized backfill	logs
lumps	marshes	masonry debris
MH	micaceous	ML
moisture (excessive)	muck	objectionable
OH	OL	organic
peat	perishable	plastic clays (highly)
PT	reef shell (fragmented)	refuse
rock	rock (unsound)	roots
rubbish	salt	scrap
settlement (will cause unacceptable)	silt	slag
sod	soft	soil cement
solids	soluble	spongy
spontaneously combustible	sticks	stone (crushed)
stones	strength (insufficient)	stumps
sulphate (soluble)	swamps	thin, flat and elongated particles
topsoil	trash	undesirable
unsound	unstable	vegetation
waste	wastes (man-made)	water saturated
weeds	wood	

unsatisfactory fill materials. Frozen material and organic material were among the most common terms encountered.

Appendix E lists the full qualitative descriptions of unsatisfactory fill materials contained in the various guide specifications. The table is arranged in alphabetical order by agency name.

FILL REQUIREMENTS: GRADATION

All of the gradation requirements found in the guide specifications for fill materials are presented in Appendix F. Some guide specifications specify detailed gradations and some specify only requirements for percentages passing for one or two sieve sizes. For example, the gradation requirement specified by the Florida DOT for fill material to be used with geosynthetic reinforcement lists percentage passing requirements for six different sieve sizes (90 mm, 19 mm, 4.75 mm, 0.425 mm, 0.150 mm, 0.075 mm). On the other hand, the gradation requirement specified by the City of Lake Oswego for fill material to be used in trenches lists the percentage passing requirement for only one sieve size (no. 200). Other guide specifications did not give numerical requirements but only qualitative descriptions of satisfactory gradations. For example, the gradation requirement specified by the Texas DOT for fill material to be used around bridge foundations states only that it must be "a gradation that permits thorough compaction."

FILL REQUIREMENTS: OTHER REQUIREMENTS

Appendix G presents any additional requirements that were specified for the fill materials in the guide specifications examined. The pH and organic

content are two of the additional requirements most commonly specified. Three guide specifications (Florida DOT, Louisiana DOT, and Tensar) require a pH in the approximate range from 5 to 10. Three guide specifications (Florida DOT, Louisiana DOT, and West Virginia DOT) also have requirements on the maximum percentage of organic content with values ranging from 2 percent to 7.5 percent.

Writing Guide Specifications for Fill Materials

Writing a guide specification can be divided into two stages: researching and writing. In this section, suggestions for researching and writing guide specifications are presented.

Where to Begin the Research

The first step in writing a guide specification for fill materials is to determine the way in which the fill materials are to be used. Once the purpose of the fill has been identified, specifications that have been written for similar purposes can be examined to understand how materials have been specified for this purpose previously. A database such as the one created in this study is an ideal tool for use at this stage. This review of current specifications might then be further narrowed to the specific region of the country where the work will take place. Guide specifications written by agencies for a particular region could prove to be invaluable resources for the specifications writer.

Specific Recommendations for Writing

In specifying requirements for fill materials, guide specifications typically take on one of four levels of specificity: 1) The guide specification does not

stipulate any requirement; 2) The guide specification states that a value must be specified for a particular fill material characteristic but gives no guidance for specifying the value; 3) The guide specification recommends a value for a particular fill material characteristic or property, but states that the value may be modified according to the specific conditions of the project; 4) The guide specification stipulates a specific value for a particular material characteristic and allows no possibility of modification. This last category may be somewhat more flexible than indicated because any requirement in a guide specification can usually be modified, with the proper analysis and approval, in the contract specification to fit the needs of the project. When beginning to write, one of the first questions that must be answered is which of the above four approaches best meets the needs of the situation being addressed.

The first approach listed above is the least desirable of the four. One should avoid saying nothing about fill material requirements. More specifically, either a value should be recommended or it should be stated clearly that the value is to be determined according to the specific needs of the project. Neglecting to provide any requirements gives the reader no guidance.

Another important consideration in writing a guide specification for fill materials is to clearly specify minimum and maximum values for fill material characteristics and not just provide examples of fill materials with acceptable characteristics. For example, suppose that an embankment that is frequently constructed by a state DOT requires a fill material with a maximum particle size

of 3 inches. Following are two possible ways to write a guide specification for this material.

> Method #1 (correct): "Fill material with a maximum particle size of 3 inches shall be used to constructed the embankment."
>
> Method #2 (ambiguous): "Soil types A and B are acceptable fill materials for use in constructing the embankment."

The first method is the correct way, but the second method is ambiguous.

In the example above, the guide specification describes two fictitious soil types, A and B, in a separate section. This is not an uncommon arrangement since these same soil types may be referred to frequently in other sections of the guide specification. Soil type A has a maximum particle size of 2 inches and soil type B has a maximum particle size of 2 ½ inches. The most reasonable interpretation of a guide specification that is written using method #2 is that 2 ½ inches is the maximum permissible particle size for the fill material to be used in the embankment. Thus, a guide specification that is written using method #2 may add unnecessarily cost to the project due to the fact that it presents requirements that are interpreted to be more stringent than necessary for the fill material. More stringent fill material requirements may translate into more expensive fill material.

Chapter 5: Summary and Conclusion

Guide specifications for fill materials are used in the preparation of the earthwork sections of specifications for individual projects. Electronic versions of guide specifications are distributed by federal agencies, state agencies, municipal agencies, and manufacturers via the Internet, by diskettes, compact disks, and digital video disks. Printed versions of guide specifications are also available. Recommendations for preparing guide specifications can also be found in engineering textbooks, handbooks, and manuals.

A database of requirements for fill materials as specified by a number of existing guide specifications was created for this study in Microsoft Access using information from 27 different sources. A database like this is a useful tool for the preparation of guide specifications for fill materials. Issues of defining the scope, choosing a software application, and entering the data were examined. Individual tables of data, queries, forms, reports, and plots were created from this database and are presented in this report. These were examined to determine the conclusions of this study. Finally, recommendations for writing guide specifications were presented based on the guide specifications examined in this study.

Maximum particle sizes stipulated in the guide specifications were found to range from 3/8 inch to 10 feet with 3 inches being the most common maximum size observed. Maximum liquid limit ranged from 15 to 90 with 35 being the most common value observed. Maximum plasticity index ranged from 4 to 65

with 6 being the most common value observed. Descriptions of what constituted satisfactory soil varied widely with sand and gravel being the most common characteristics cited. Descriptions of unsatisfactory soil also varied widely with frozen material and organic material being cited most often as unsatisfactory materials. Twenty of the 27 sources included in the database specify either a qualitative or quantitative requirement for fill materials based on grain size distribution. Eight of the 27 sources also specify additional requirements for fill materials with pH and organic content being the items most commonly stipulated as additional requirements.

This study has introduced the most commonly specified characteristics of fill materials. Specific examples of the numerical values and textual descriptions used by a number of agencies have also been presented. Conclusions drawn from these examples have been presented above and should be useful for writing both guide specifications and specifications unique to individual projects.

Appendix A: All Fill Material Requirements Grouped by Purpose

All Fill Material Requirements Grouped by Purpose

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Bedding (For Sidewalks And Curbing)	AASHTO 1984	Cinders, sand, slag, gravel, or crushed stone.	Not specified.	1/2 inch.	Not specified.	Not specified.	Not specified.	Not specified.
Bedding (For Slope Protection)	AASHTO 1984	Porous, free-draining material consisting of sand, gravel, cinders, slag, or crushed stone.	Not specified.	1 1/2 inches.	Uniformly graded.	Not specified.	Not specified.	Not specified.
Bedding (General)	IL DOT 1997	Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand.	Material containing an excess of soft and unsound particles and other objectionable matter.	3/8 inch.	FA 1 / FA 2 9.5 mm: 100 / 100 4.57 mm: 97±3 / 97±3 1.18 mm: 65±20 / 65±20 0.300 mm: 16±13 / 20±10 0.150 mm: 5±5 / 5±5 0.075 mm: 2±2 / 2±2	Not specified.	Not specified.	Not specified.
	LA DOT 1992	Stone, recycled portland cement concrete, expanded clay, shell, gravel, crushed slag, or sand.	Not specified.	Not specified.	Extensive gradation requirements that are too lengthy and detailed to include in this database.	Not specified.	Nonplastic (for sand, stone, and recycled portland cement concrete passing the no. 40 sieve).	Not specified.
	Lake Oswego 1999	Imported crushed rock.	Material containing dirt, clay balls, and organic material.	1 inch.	Less than 8% passing the No. 200 sieve.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Bedding (General)	Navy 1998	Sand, gravel, or crushed rock composed of tough, durable particles. ASTM D2321 Materials: Class I: Angular stone (including coral, slag, cinders, crushed stone, and crushed shells where available). Class II: Coarse sands and gravels including graded sands and gravels containing small percentages of fines, generally granular and noncohesive, wet or dry (this includes GW, GP, SW, and SP).	Not specified.	2 inches.	Class I: Sizes from 0.25 to 1.5 in. Class II: Max size of 1.5 in.	Not specified.	6 (for material passing the 0.075 mm sieve).	Not specified.
Blankets (For Stone Protection)	AASHTO 1984	Gravel, crushed gravel, crushed stone, crushed air-cooled blast-furnace slag, or crushed concrete.	Not specified.	2 1/2 inches.	AASHTO M 43, size No. 357: mm % 63 100 50 95-100 25 35-70 12.5 10-30 4.75 0-5	Not specified.	Not specified.	Not specified.
Blankets (Plastic Soil)	LA DOT 1992	Not specified.	Large or frozen lumps, stones, roots, wood, and other foreign matter.	Not specified.	Not specified.	Not specified.	12 to 35.	pH from 5.5 to 8.5.
Capillary Water Barrier (Under Concrete Slabs)	Army COE 1997	Clean, crushed, nonporous rock, crushed gravel, or uncrushed gravel.	Not specified.	1 1/2 inches.	4.75 mm no more than 2%	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Capillary Water Barrier (Under Concrete Slabs)	Navy 1998	Clean crushed stone, crushed gravel, or uncrushed gravel. Clean concrete sand (for capillary water barrier underlay or for capillary water barrier not under slabs).	Not specified.	Not specified.	Underlay: 3% passing 0.075 mm sieve.	Not specified.	Not specified.	Not specified.
Culverts	TX DOT 1993	Stone or lean concrete (only if backfilling an excavation in hard material resistant to erosion).	Not specified.	4 inches.	A gradation that permits thorough compaction.	Not specified.	Not specified.	Not specified.
	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	3 inches.	75 mm 100% 4.75 mm not less than 25% Of all material passing 4.75 mm sieve: 0.075 mm not more than 15%	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Drains (Subsurface)	AASHTO 1984	Hard, durable, clean sand, gravel, crushed stone, or crushed slag.	Organic material, clay balls, or other deleterious substances.	1/2 inch (Course Aggregate). 3/8 inch (Fine Aggregate).	Course Aggregate (AASHTO M 43, size No. 89): mm % 12.5 100 9.5 90-100 4.75 20-55 2.36 5-30 1.18 0-10 0.300 0-5 Fine Aggregate (AASHTO M 6): mm % 9.5 100 4.75 95-100 1.18 45-80 0.300 10-30 0.150 2-10	Not specified.	Not specified.	Not specified.
	IL DOT 1997	Fine Aggregates: Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand. Course Aggregates: Gravel, crushed gravel, pit run gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone, or wet bottom boiler slag.	Not specified.	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).	Course Aggregates: CA 18 75 mm 100 25 mm 95±5 4.75 mm 75±25 1.18 mm 55±25 0.300 mm 10±10 0.075 mm 2±2 Fine Aggregates: FA 1 FA 2 9.5 mm 100 100 4.57 mm 97±3 97±3 1.18 mm 65±20 65±20 0.300 mm 16±13 20±10 0.150 mm 5±5 5±5 0.075 mm 2±2 2±2	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Drains (Subsurface)	Lake Oswego 1999	Washed round rock.	Not specified.	Not specified.	Graded from 1.5 inches to 3/4 inches.	Not specified.	Not specified.	Not specified.
	NASA 1997	Uniformly graded mixture of natural or crushed gravel, crushed stone, and natural sand.	Not specified.	3/8 inch.	9.5 mm 100% 0.150 mm 2-10%	Not specified.	Not specified.	Not specified.
	Navy 1998	Clean sand, stone, or gravel fill.	Not specified.	A size that will prevent the entrance of any of the porous material into the drain.	a. Perforated or slotted wall pipe: Type I. b. Open joint pipe: Type I and Type II (i.e. two soils used as a combination). c. Blind or french drains: Type II. c. Any pipe used with filter fabric: Type I, or Type II. Type I / Type II 37.5 mm -- / 100 25.0 mm -- / 90-100 9.5 mm 100 / 25-60 4.75 mm 95-100 / 5-40 2.36 mm -- / 0-20 1.18 mm 45-80 / -- 0.300 mm 10-30 / -- 0.150 mm 0-10 / --	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Drains (Subsurface)	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	6 inches. 1 inch (for pipe bedding).	150 mm 100% 75 mm not less than 85% 4.75 mm not less than 25% Of material passing 4.75 mm sieve: Grade 1: 4.75 mm 100% 0.425 mm not more than 75% 0.150 mm not more than 15% 0.075 mm not more than 8% Grade 2: 4.75 mm 100% 0.425 mm - 0.150 mm not more than 30% 0.075 mm not more than 15%	25	6	Not specified.
	WV DOT 1994	Random material (a mixture of any or all of soil, granular material, or soft shale).	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
Embankments (Dam, Impervious Soil)	Army COE 1997	Clays, silty clays, or clayey silts. Silts and clays containing sand may be used if sufficiently impermeable and suitable for compacting with a tamping or rubber-tired roller.	Materials containing brush, roots, sod or other perishable materials.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
Embankments (Dam, Pervious Soil)	Army COE 1997	Clean, free draining sand or sand and gravel free from any objectionable coating.	Materials containing brush, roots, sod or other perishable materials.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (General)	AASHTO 1984	Not specified.	Soil that cannot be properly compacted, sod, and vegetable matter. Rocks, broken concrete, or other solid materials (where piling will be driven).	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
	FAA 1991	Not specified.	Frozen material or material containing vegetable or organic matter, such as muck, peat, organic silt, or sod.	4 inches (within top 6 inches of embankment).	Not specified.	Not specified.	Not specified.	Not specified.
	FL DOT 1999	Not specified.	Material containing muck, stumps, roots, brush, vegetable matter, rubbish, or other material that does not compact into a suitable and enduring roadbed.	3.5 inches (0-12 inches depth or within 3 feet of bridge piling). 6 inches (12-24 inches depth). 12 inches or compacted thickness of layer (below 24 inches depth).	A gradation that minimizes voids between particles.	Not specified.	Not specified.	Not specified.
	Houston 1997	Not specified.	Material containing lumps (greater than 6 inches), organic material, chemical waste or other contamination, and debris.	3 inches.	Not specified.	45.	12 to 20 (do not use a blend cohesive and granular soils to achieve this value).	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (General)	IL DOT 1997	Earth, stone, or gravel.	Sod, frozen material, or any material which by decay or otherwise, might cause settlement	4 inches (within top 12 inches of fill or top 3 inches of fill under pavement, surface course, or base course). Concrete and rocks with less than 2 sqft on any face may be placed in fill in layers less than 12 inches thick if well embedded and surrounded by enough smaller particles to give the required density.	Not specified.	Not specified.	Not specified.	Not specified.
	Lake Oswego 1999	Native excavated material.	Material containing weeds, refuse, sticks, or other organic material which in the Engineer's opinion would compromise the integrity of the compacted trench.	1 inch.	3 inch more than 90% 1 inch more than 50% no. 200 not more than 20%	Not specified.	Not specified.	Not specified.
	MD DOT 1993	Not specified.	Frozen material.	24 inches.	Not specified.	Not specified.	Not specified.	Not specified.
	NASA 1997	Not specified.	Not specified.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (General)	NM DOT 1994	Not specified.	Frozen material. Material containing rock, broken concrete, or other solid materials (where piling, utilities, or structures are to be built).	36 inches. 10 feet or 1/2 of the embankment height (near the toe of the slope).	Not specified.	Not specified.	Not specified.	Not specified.
	SHCE 1996	Not specified.	Material containing organic matter.	3 inches (within 18 inches of foundations, slabs, or ground surface).	Not specified.	Not specified.	Not specified.	Not specified.
	TX DOT 1993	Rock, loam, clay, or other materials.	Material containing organic or otherwise deleterious matter or unacceptable lumps of earth.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
	USBR 1999	Not specified.	PT, OL, OH. Material containing roots, stumps, limbs, vegetation, organic matter, ice, construction debris, scrap materials, refuse, man-made wastes, or chemical or hydrocarbon contamination.	5 inches.	Not specified.	Not specified.	Not specified.	Not specified.
	UT DOT 1994	Granular material.	Not specified.	2-3 inches.	Not specified.	Not specified.	Nonplastic.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (General)	WI DOT 1996	Not specified.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	A size that would significantly affect scarifying, compacting, and finishing the subgrade (within 8 inches of the surface). 3 inches or a size that would significantly affect driving of piles or boring of holes (where piles driven or holes bored).	Not specified.	Not specified.	Not specified.	Not specified.
	WV DOT 1994	Random material (a mixture of any or all of soil, granular material, or soft shale), hard shale, or rock. Preference given to granular soils.	Materials which cannot be satisfactorily placed and compacted to a stable and durable condition. Sod, trash, organic substances beyond the allowed percentage, or muck. Soil that contains excessive moisture. Soil containing stumps and spongy or frozen soil. When piles driven: soil containing rock.	Not specified.	Not specified.	Not specified.	Not specified.	Organic content shall be less than 7.5% by weight.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (General, Pervious Soil)	IL DOT 1997	Fine Aggregates: Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand. Course Aggregates: Gravel, crushed gravel, pit run gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone, or wet bottom boiler slag.	Not specified.	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).	Course Aggregates: CA 18 75 mm 100 25 mm 95±5 4.75 mm 75±25 1.18 mm 55±25 0.300 mm 10±10 0.075 mm 2±2 Fine Aggregates: FA 1 FA 2 9.5 mm 100 100 4.57 mm 97±3 97±3 1.18 mm 65±20 65±20 0.300 mm 16±13 20±10 0.150 mm 5±5 5±5 0.075 mm 2±2 2±2	Not specified.	Not specified.	Not specified.
Embankments (Granular)	IL DOT 1997	Pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag, or crushed sandstone.	Not specified.	1 inch (for gradation CA 6). 1 1/2 inches (for gradation CA 10).	CA 6 CA 10 37.5 mm 100 -- 25 mm 95±5 100 19 mm -- 95±5 12.5 mm 75±15 80±15 4.75 mm 43±13 50±10 1.18 mm 25±15 30±15 0.075 mm 8±4 9±4	Not specified.	6 (for gravel). 4 (for crushed gravel, stone, and slag but waived if [%passing 0.075 sieve] / [%passing 0.425 sieve] is 0.60 or less).	Bearing Ratio not less than 80 (for embankment fill only except when crushed gravel, crushed stone, or crushed slag used). Na2SO4 Soundness 5 Cycle: maximum loss 25%. Los Angeles Abrasion: maximum loss 45%.
	TX DOT 1993	Granular material.	Material containing organic or otherwise deleterious matter or unacceptable lumps of earth.	Not specified.	Not specified.	45	15	Bar Linear Shrinkage not greater than 2.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Embankments (Nonplastic Soil)	LA DOT 1992	Sand, clam shell, or reef shell.	Water saturated soils, organic matter, material not usable for foundation material, or material which will decay or produce subsistence in the soil such as stumps, roots, logs, or humus. Large amounts of fragmented reef shell.	Not specified.	Sand No. 4 75% No. 200 15% Shell No. 200 15%	Not specified.	Nonplastic.	Organic content of 4% or less.
Embankments (Soil Above 8 ft Depth)	LA DOT 1992	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	20 (20 to 35 if treated with at least 6% lime).	Organic content less than 5%. Silt content of 60% or less.
Embankments (Soil Below 8 ft Depth)	LA DOT 1992	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	35 (35 to 45 if treated with at least 10% lime).	Organic content less than 5%. Silt content of 60% or less.
Embankments (W/in 1000 ft Of Bridge End)	LA DOT 1992	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	10 to 20.	Organic content less than 5%. Silt content of 60% or less.
Filters (Blanket)	AASHTO 1984	Gravel, crushed gravel, crushed stone, crushed air-cooled blast-furnace slag, or crushed concrete.	Not specified.	2 inches.	AASHTO M 43, size No. 467: mm % 50 100 37.5 95-100 19 35-70 9.5 10-30 4.75 0-5	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Filters (For Dam Embankments)	Army COE 1997	Tough, durable particles of sand, gravel, or crushed stone.	Material containing thin, flat and elongated particles and/or soft, friable particles in objectionable quantities or material containing brush, roots, sod or other perishable materials.	Not specified.	Grading curves shall not exhibit abrupt changes in slope denoting skip grading, scalping of certain sizes, or other irregularities which would be detrimental to the proper functioning of the filter.	Not specified.	Not specified.	Not specified.
Filters (For Rip-Rap)	AASHTO 1984	Hard, durable particles or fragments of crushed stone or natural gravel.	Not specified.	3 inches.	3 in 100% no. 4 20-50% no. 200 0-10%	Not specified.	Not specified.	Not specified.
Foundations (Bridge)	TX DOT 1993	Stone or lean concrete (only if backfilling an excavation in hard material resistant to erosion).	Not specified.	4 inches.	A gradation that permits thorough compaction.	Not specified.	Not specified.	Not specified.
	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	3 inches.	75 mm 100% 4.75 mm not less than 25% Of all material passing 4.75 mm sieve: 0.075 mm not more than 15%	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Foundations (General)	Houston 1997	GW and SW. Well-graded gravels and sands, gravel-sand mixtures, crushed well-graded rock, little or no fines.	ML, CL-ML, MH, PT, OH, and OL. Materials that contain large clods, aggregates, debris, vegetation, waste or any other deleterious materials, hydrocarbons or other chemical contaminants. Materials that cannot be compacted to the required density due to either gradation, plasticity, or moisture content.	4 inches.	D60/D10 greater than 4% no 200 not greater than 5%	Not specified.	Nonplastic.	Not specified.
	LA DOT 1992	Not specified.	Large or frozen lumps, stones, roots, wood, and other foreign matter.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
	Navy 1998	GW, GP, SW, or SP.	Not specified.	2 1/2 inches.	2 1/2 in 100% No. 4 40-85% No. 10 20-80% No. 40 10-60% No. 200 5-35% (10% for crib wall)	35	12	Coefficient of permeability shall be a minimum of 0.01-1 mm/sec (0.002-0.2 ft/min).
General Fill	Army COE 1997	GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, SP-SM, SP-SC, CL, ML, CL-ML, CH, or MH.	Materials containing man-made fills, trash, refuse, backfills from previous construction, roots, organic matter, frozen materials, or contaminated materials.	Half of the allowable lift thickness. 8 inches (for grading). 3 inches (for pavements and railroads).	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
General Fill	CGSF 1988	Predominantly sand or sand and gravel.	Material containing clods, wood, or masonry debris, or other deleterious material.	Not specified.	Not more than 20% passing the No. 200 sieve.	Not specified.	Not specified.	Not specified.
	LA DOT 1992	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	20	Organic content less than 5%. Silt content of 60% or less.
	LANL 1997	Granular soil.	Material containing organic material or other deleterious materials.	Not specified.	Not specified.	Not specified.	Nonplastic.	Not specified.
	NASA 1997	AASHTO M 145 Classification Groups A-1 (well graded mixture of stone fragments or gravel, coarse sand, fine sand and a nonplastic or feebly plastic soil binder, volcanic cinders without soil binder), A-2-4 and A-2-5 (gravel or coarse sand containing silt; fine sand containing nonplastic silt), and A-3 (fine beach sand and fine desert blow sand without silty or clay fines; stream deposited mixture of poorly graded fine sand, coarse sand, and gravel).	AASHTO M 145 Classification Groups A-2-6 and A-2-7(A-2-4 and A-2-5 soils containing plastic clay), A-4 (nonplastic or moderately plastic silty soil; fine silty soil), A-5 (diatomaceous or micaceous A-4 soils), A-6 (plastic clay soil; fine clayey soil), and A-7 (diatomaceous or micaceous A-6 soils), peat and other highly organic soil. Materials containing clay clods, debris, waste, frozen materials, or other deleterious matter.	2 inches.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
General Fill	Navy 1998	GW, GP, GM, GC, SW, SP, SM, or SC.	Material containing debris, roots, wood, scrap material, vegetation, refuse, soft unsound particles, frozen, deleterious, or objectionable materials.	Half of the allowable lift thickness.	0.075 mm 25%	35	12	Not specified.
	Scotland DOT 1976	Not specified.	Material from swamps, marshes, and bogs; peat, logs, stumps, and perishable materials; material susceptible to spontaneous combustion; frozen material.	Not specified.	Not specified.	90	65	Not specified.
	VA 1996	Not specified.	Topsoil, frozen materials, construction materials, materials subject to decomposition, clods of clay, organic material, including silts, which are unstable, and inorganic materials, including silts, too wet to be stable.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.
	WV DOT 1994	Random material (a mixture of any or all of soil, granular material, or soft shale).	Material containing frozen lumps, wood, or other extraneous material.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.
General Fill (Against Waterproofed Surfaces)	NASA 1997	Natural sand.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation		Max Liquid Limit	Max Plasticity Index	Other Requirements
General Fill (Below Water Table)	Scotland DOT 1976	Granular material.	Not specified.	15 3/4 inches.	10 mm 5 mm 0.6 mm 0.075 mm	up to 100% not more than 85% not more than 45% not more than 5%	Not specified.	Not specified.	Not specified.
General Fill (Select, Controlled)	LA DOT 1992	Natural soil.	Not specified.	Not specified.	Not specified.		35	15	Organic content of 2% or less. Silt content of 60% or less.
	WV DOT 1994	Crushed stone: particles of clean, hard, tough, durable rock, OR Gravel: particles of hard, durable rock, thoroughly clean and well graded, OR Slag: air cooled blast-furnace slag, reasonably uniform in density and quality.	Crushed stone: particles with adherent coatings. Slag: slag containing dirt or other objectionable matter.	2 inches.	50 mm 1.18 mm	100% 0-5%	Not specified.	Not specified.	Crushed stone: Percentage wear not to exceed 40. Soundness loss not to exceed 12. Percent by weight maximums: thin or elongated pieces 5%, shale 1%, coal and other lightweight deleterious material 1.5%, friable particles 0.25%.
Geosynthetic Reinforcement (General)	FL DOT 1999	Free draining material.	Soil cement or lime stabilized backfill.	3 1/2 inches.	90 mm 19 mm 4.75 mm 0.425 mm 0.150 mm 0.075 mm	100% 70 to 100% 30 to 100% 15 to 100% 5 to 65% 0 to 15%	15	6	Organic material: not more than 2% by weight. pH from 6 to 10.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Geotextile Fabric Covering	IL DOT 1997	Pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag, or crushed sandstone.	Not specified.	1 inch (for gradation CA 6). 1 1/2 inches (for gradation CA 10).	CA 6 CA 10 37.5 mm 100 -- 25 mm 95±5 100 19 mm -- 95±5 12.5 mm 75±15 80±15 4.75 mm 43±13 50±10 1.18 mm 25±15 30±15 0.075 mm 8±4 9±4	Not specified.	6 (for gravel). 4 (for crushed gravel, stone, and slag but waived if [%passing 0.075 sieve] / [%passing 0.425 sieve] is 0.60 or less).	Bearing Ratio not less than 80 (for embankment fill only except when crushed gravel, crushed stone, or crushed slag used). Na2SO4 Soundness 5 Cycle: maximum loss 25%. Los Angeles Abrasion: maximum loss 45%.
Pipe Arches and Structural Plate Pipes	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	3 inches.	75 mm 100% 4.75 mm not less than 25% Of all material passing 4.75 mm sieve: 0.075 mm not more than 15%	Not specified.	Not specified.	Not specified.
Retaining Walls (Crib Type)	Navy 1998	GW, GP, SW, or SP.	Not specified.	2 1/2 inches.	2 1/2 in 100% No. 4 40-85% No. 10 20-80% No. 40 10-60% No. 200 5-35% (10% for crib wall)	35	12	Coefficient of permeability shall be a minimum of 0.01-1 mm/sec (0.002-0.2 ft/min).
Retaining Walls (General)	LA DOT 1992	Not specified.	Large or frozen lumps, stones, roots, wood, and other foreign matter.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Retaining Walls (General)	TX DOT 1993	Stone or lean concrete (only if backfilling an excavation in hard material resistant to erosion).	Not specified.	4 inches.	A gradation that permits thorough compaction.	Not specified.	Not specified.	Not specified.
	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.	3 inches.	75 mm 100% 4.75 mm not less than 25% Of all material passing 4.75 mm sieve: 0.075 mm not more than 15%	Not specified.	Not specified.	Not specified.
Retaining Walls (MSE Type)	DERS 1999	Not specified.	Material containing organic matter.	4-6 inches. 3/4 inch (where geofabrics or metals coated with PVC or epoxy are used).	6 inch 100% 3 inch 10-75% no. 200 0-25% 4 inch 100% no. 40 0-60% no. 200 0-15%	Not specified.	6	Angle of internal friction not less than 34 degrees.
	Geostone	On-site dewatered, compatible selected fill and crushed stone.	Not specified.	1 1/2 inches (unless field tests have been performed to elevate potential strength reduction in the geosynthetic due to installation damage).	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Retaining Walls (MSE Type)	Keystone 1994	Site excavated soils.	Material containing debris. Highly plastic clays or organic soils.	3/4 inch (unless field tests evaluate potential strength reductions to the geogrid design due to damage during construction).	2 inch 100-75% 3/4 inch 100-75% No. 4 100-20% No. 40 0-60% No. 200 0-35%	40	10	Not specified.
	Tensar 1997	Granular soil. Recycled concrete if high density polyethylene or polypropylene geogrid is used.	Not specified.	2 inches.	2 inch 100-75% 3/4 inch 100-75% no 4 100-20% no 40 0-60% no 200 0-35%	Not specified.	Not specified.	pH from 5 to 9 (waived when high density polyethylene or polypropylene geogrid is used).
	TX DOT 1993	Not specified.	Material containing organic or otherwise deleterious matter.	3/4 inch (for nonmetallic or epoxy coated reinforcement). 3 inches (for gradation A). 6 inches (for gradation B).	Gradation A: 3 inches 100% No. 40 0-60% No. 200 0-15% Gradation B: 6 inches 100% 3 inches 75-100% No. 200 0-15% 15-25% (Alternative)	Not specified.	6 (for gradation B).	Angle of internal friction not less than 34 degrees at 95% of Da density (only for Alternative Type B).
Retaining Walls (Spread Footing Type)	TX DOT 1993	Rock, loam, clay, or other materials.	Material containing organic or otherwise deleterious matter or unacceptable lumps of earth.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
Slabs	NASA 1997	Washed, uniformly graded mixture of crushed stone or crushed or uncrushed gravel.	Not specified.	1 1/2 inches.	37.5 mm 100% 4.75 mm not more than 5%	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Slabs	Navy 1998	GW, GP, SW, or SP.	Not specified.	2 1/2 inches.	2 1/2 in 100% No. 4 40-85% No. 10 20-80% No. 40 10-60% No. 200 5-35% (10% for crib wall)	35	12	Coefficient of permeability shall be a minimum of 0.01-1 mm/sec (0.002-0.2 ft/min).
	VA 1996	Crushed stone or gravel.	Not specified.	1 inch.	Graded from 25 mm (1 inch) to No. 4.	Not specified.	Not specified.	Not specified.
Structures (Against Sides Above Drains)	Keystone 1994	Clean crushed stone or crushed gravel.	Material containing debris. Highly plastic clays or organic soils.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
	NASA 1997	Uniformly graded mixture of natural or crushed gravel, crushed stone, and natural sand.	Not specified.	3/8 inch.	9.5 mm 100% 0.150 mm 2-10%	Not specified.	Not specified.	Not specified.
Structures (Against Sides)	Navy 1998	GP, GM, GC, SP, or SM.	Soft, spongy, highly plastic, or otherwise unstable material.	3 inches.	Shall contain sufficient fines to ensure proper compaction.	Not specified.	Not specified.	Not specified.
	OR DOT 1996	Granular material composed of crushed and/or uncrushed rock.	Not specified.	3 inches.	75 mm 100% 9.5 mm 0 - 80% 425 mm 0 - 40% 150 mm 0 - 10% 75 mm 0 - 6%	Not specified.	6 (for material passing 0.425 mm sieve).	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation		Max Liquid Limit	Max Plasticity Index	Other Requirements
Structures (Against Sides)	Scotland DOT 1976	Well graded crushed or uncrushed gravel, stone, rock fill, crushed concrete or slag or natural sand or a combination of any of these.	Soluble sulphate content < 2.5 g/L.	0.015 cubic meters.	125 mm 75 mm 0.075 mm	not less than 95% at least 90% not more than 10%	Not specified.	Not specified.	Not specified.
Structures (General)	Army COE 1997	GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, SP-SM, SP-SC, CL, ML, CL-ML, CH, or MH.	OL, OH, and PT. Materials containing man-made fills, trash, refuse, backfills from previous construction, roots, organic matter, frozen materials, or contaminated materials.	3 inches.	Not specified.		Not specified.	Not specified.	Not specified.
	Lake Oswego 1999	Imported crushed rock.	Not specified.	2 inches.	Well graded from course to fine with no more than 8% by weight passing the No. 200 sieve.		Not specified.	Not specified.	Not specified.
	Navy 1998	GP, GM, GC, SP, SM, or SC.	PT, OH, or OL. Material containing debris, refuse, roots, wood, scrap materials, vegetable matter, frozen material, or material having insufficient strength or stability to carry intended loads without excessive consolidation or loss of stability. Man-made fills, uncompacted backfills from previous construction, unsound rock or soil lenses, or other deleterious or objectionable material.	3 inches.	Not specified.		Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Structures (General)	NM DOT 1994	Stone, crushed stone, crushed or screened gravel, caliche, or sand.	Material free from organic matter, silt, clay balls, frozen matter, or other deleterious matter.	2 inches.	No. 200 25%	Not specified.	6 (for material passing No. 200 sieve).	Not specified.
	OR DOT 1996	Granular material consisting of crushed, durable rock.	Not specified.	2 inches.	50 mm 100% 12.5 mm 50 - 80% 4.75 mm 35 - 70% 425 mm 15 - 35% 150 mm 0 - 15%	Not specified.	6 (for material passing 0.425 mm sieve).	Not specified.
	TX DOT 1993	Cohesionless materials, such as sand.	Material containing wood, other extraneous material, frozen lumps, or large lumps that would not break down readily under compaction.	A size that would interfere with compaction.	Not specified.	Not specified.	Not specified.	Not specified.
Structures (Non-Frost Susceptible Soil)	Army COE 1997	Washed sand.	ML, MH, and CH for critical structures.	Not specified.	0.075 mm less than 5% 0.020 mm not more than 2%	Not specified.	Not specified.	Not specified.
Trenches (General)	Army COE 1997	GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, SP-SM, SP-SC, CL, ML, CL-ML, CH, or MH.	Materials containing man-made fills, trash, refuse, backfills from previous construction, roots, organic matter, frozen materials, or contaminated materials.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation		Max Liquid Limit	Max Plasticity Index	Other Requirements
Trenches (General)	FL DOT 1999	Naturally occurring materials such as gravel, or resulting from the crushing of parent rock, to include natural rock, slags, expanded clays and shales (lightweight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles.	Material containing unreasonable amounts of clay lumps, soft and friable particles, salt, alkali, organic matter, adherent coatings, and other substances not defined which may possess undesirable characteristics.	3/4 inch.	19 mm 12.5 mm 9.5 mm 4.75 mm 2.36 mm	100% 90-100% 40-70% 0-15% 0-5%	Not specified.	Not specified.	Los Angeles Abrasion: maximum loss 45%. Soundness (Sodium Sulfate): maximum loss 12%. Flat or elongated pieces: maximum 10%.
	IL DOT 1997	Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand.	Material containing an excess of soft and unsound particles and other objectionable matter.	Not specified.	 4.75 mm 0.150 mm 0.075 mm	FA 6 92±8 20±20 6±6	Not specified.	Not specified.	Not specified.
	Lake Oswego 1999	Imported crushed rock.	Material containing dirt, clay balls, and organic material.	1 inch.	Less than 8% passing the No. 200 sieve.		Not specified.	Not specified.	Not specified.
	NASA 1997	Sandy clay, sand, gravel, soft shale.	Not specified.	Not specified.	Not specified.		Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Trenches (General)	Navy 1998	GM, SM, or SC.	PT, OH, or OL. Material containing debris, refuse, roots, wood, scrap materials, vegetable matter, frozen material, or material having insufficient strength or stability to carry intended loads without excessive consolidation or loss of stability. Large rocks, soft unsound particles, soluble particles, or other material which could damage the pipe or cause the backfill not to compact.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.
	WV DOT 1994	Random material (a mixture of any or all of soil, granular material, or soft shale) or crushed aggregate.	Not specified.	3 inches.	Not specified.	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Trenches (Permeable Soil)	AASHTO 1984	Hard, durable, clean sand, gravel, crushed stone, or crushed slag.	Organic material, clay balls, or other deleterious substances.	1/2 inch (Course Aggregate). 3/8 inch (Fine Aggregate).	Course Aggregate (AASHTO M 43, size No. 89): mm % 12.5 100 9.5 90-100 4.75 20-55 2.36 5-30 1.18 0-10 0.300 0-5 Fine Aggregate (AASHTO M 6): mm % 9.5 100 4.75 95-100 1.18 45-80 0.300 10-30 0.150 2-10	Not specified.	Not specified.	Not specified.
	IL DOT 1997	Fine Aggregates: Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand. Course Aggregates: Gravel, crushed gravel, pit run gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone, or wet bottom boiler slag.	Not specified.	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).	Course Aggregates: CA 18 75 mm 100 25 mm 95±5 4.75 mm 75±25 1.18 mm 55±25 0.300 mm 10±10 0.075 mm 2±2 Fine Aggregates: FA 1 FA 2 9.5 mm 100 100 4.57 mm 97±3 97±3 1.18 mm 65±20 65±20 0.300 mm 16±13 20±10 0.150 mm 5±5 5±5 0.075 mm 2±2 2±2	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Trenches (Sanitary/Storm Sewer Bedding)	VA 1996	Crushed stone or gravel.	Not specified.	1/2 inch.	Graded from 13 mm (1/2 inch) to No. 4.	Not specified.	Not specified.	Not specified.
Trenches (Select Soil)	Army COE 1997	Well-graded sand, gravel, crushed gravel, crushed stone or crushed slag composed of hard, tough and durable particles.	Not specified.	3 inches or 1 inch per foot of pipe diameter.	25 mm not less than 95% 0.075 mm not more than 10%	Not specified.	Not specified.	Not specified.
	WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.	Not specified.	6 inches. 1 inch (for pipe bedding).	150 mm 100% 75 mm not less than 85% 4.75 mm not less than 25% Of material passing 4.75 mm sieve: Grade 1: 4.75 mm 100% 0.425 mm not more than 75% 0.150 mm not more than 15% 0.075 mm not more than 8% Grade 2: 4.75 mm 100% 0.425 mm - 0.150 mm not more than 30% 0.075 mm not more than 15%	25	6	Not specified.
Trenches (Sewage Absorption)	Navy 1998	Clean crushed rock or gravel.	Not specified.	2 inches.	50 mm 100% 12.5 mm 0%	Not specified.	Not specified.	Not specified.

Purpose	Agency	Satisfactory Soil	Unsatisfactory Soil	Max Particle Size	Gradation	Max Liquid Limit	Max Plasticity Index	Other Requirements
Trenches (Stabilization Of)	Lake Oswego 1999	Imported crushed rock or gravel or clean pit run gravel.	Not specified.	3 inches.	Well graded from course to fine with no more than 8% by weight passing the No. 200 sieve.	Not specified.	Not specified.	Not specified.
Trenches (Under Paved Areas)	Navy 1998	GW, GP, SW, or SP.	Not specified.	2 1/2 inches.	2 1/2 in 100% No. 4 40-85% No. 10 20-80% No. 40 10-60% No. 200 5-35% (10% for crib wall)	35	12	Coefficient of permeability shall be a minimum of 0.01-1 mm/sec (0.002-0.2 ft/min).
	TX DOT 1993	Not specified.	Not specified.	Not specified.	Less than 20% passing 3 inch sieve.	Not specified.	Not specified.	Not specified.

Appendix B: Maximum Particle Size Grouped by Purpose

Maximum Particle Size Grouped by Purpose

Purpose	Agency	Maximum Particle Size
Bedding (For Sidewalks And Curbing)	AASHTO 1984	1/2 inch.
Bedding (For Slope Protection)	AASHTO 1984	1 1/2 inches.
Bedding (General)	IL DOT 1997	3/8 inch.
	Lake Oswego 1999	1 inch.
	Navy 1998	2 inches.
Blankets (For Stone Protection)	AASHTO 1984	2 1/2 inches.
Capillary Water Barrier (Under Concrete Slabs)	Army COE 1997	1 1/2 inches.
Culverts	TX DOT 1993	4 inches.
	WI DOT 1996	3 inches.
Drains (Subsurface)	AASHTO 1984	1/2 inch (Course Aggregate). 3/8 inch (Fine Aggregate).
	IL DOT 1997	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).
	NASA 1997	3/8 inch.

Purpose	Agency	Maximum Particle Size
Drains (Subsurface)	Navy 1998	A size that will prevent the entrance of any of the porous material into the drain.
	WI DOT 1996	6 inches. 1 inch (for pipe bedding).
Embankments (General)	FAA 1991	4 inches (within top 6 inches of embankment).
	FL DOT 1999	3.5 inches (0-12 inches depth or within 3 feet of bridge piling). 6 inches (12-24 inches depth). 12 inches or compacted thickness of layer (below 24 inches depth).
	Houston 1997	3 inches.
	IL DOT 1997	4 inches (within top 12 inches of fill or top 3 inches of fill under pavement, surface course, or base course). Concrete and rocks with less than 2 sqft on any face may be placed in fill in layers less than 12 inches thick if well embedded and surrounded by enough smaller particles to give the required density.
	Lake Oswego 1999	1 inch.
	MD DOT 1993	24 inches.
	NASA 1997	3 inches.
	NM DOT 1994	36 inches. 10 feet or 1/2 of the embankment height (near the toe of the slope).
	SHCE 1996	3 inches (within 18 inches of foundations, slabs, or ground surface).

Purpose	Agency	Maximum Particle Size
Embankments (General)	USBR 1999	5 inches.
	UT DOT 1994	2-3 inches.
	WI DOT 1996	A size that would significantly affect scarifying, compacting, and finishing the subgrade (within 8 inches of the surface). 3 inches or a size that would significantly affect driving of piles or boring of holes (where piles driven or holes bored).
Embankments (General, Pervious Soil)	IL DOT 1997	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).
Embankments (Granular)	IL DOT 1997	1 inch (for gradation CA 6). 1 1/2 inches (for gradation CA 10).
Filters (Blanket)	AASHTO 1984	2 inches.
Filters (For Rip-Rap)	AASHTO 1984	3 inches.
Foundations (Bridge)	TX DOT 1993	4 inches.
	WI DOT 1996	3 inches.
Foundations (General)	Houston 1997	4 inches.
	Navy 1998	2 1/2 inches.
General Fill	Army COE 1997	Half of the allowable lift thickness. 8 inches (for grading). 3 inches (for pavements and railroads).

Purpose	Agency	Maximum Particle Size
General Fill	NASA 1997	2 inches.
	Navy 1998	Half of the allowable lift thickness.
	VA 1996	3 inches.
	WV DOT 1994	3 inches.
General Fill (Below Water Table)	Scotland DOT 1976	15 3/4 inches.
General Fill (Select, Controlled)	WV DOT 1994	2 inches.
Geosynthetic Reinforcement (General)	FL DOT 1999	3 1/2 inches.
Geotextile Fabric Covering	IL DOT 1997	1 inch (for gradation CA 6). 1 1/2 inches (for gradation CA 10).
Pipe Arches and Structural Plate Pipes	WI DOT 1996	3 inches.
Retaining Walls (Crib Type)	Navy 1998	2 1/2 inches.
Retaining Walls (General)	TX DOT 1993	4 inches.
	WI DOT 1996	3 inches.
Retaining Walls (MSE Type)	DERS 1999	4-6 inches. 3/4 inch (where geofabrics or metals coated with PVC or epoxy are used).

Purpose	Agency	Maximum Particle Size
Retaining Walls (MSE Type)	Geostone	1 1/2 inches (unless field tests have been performed to elevate potential strength reduction in the geosynthetic due to installation damage).
	Keystone 1994	3/4 inch (unless field tests evaluate potential strength reductions to the geogrid design due to damage during construction).
	Tensar 1997	2 inches.
	TX DOT 1993	3/4 inch (for nonmetallic or epoxy coated reinforcement). 3 inches (for gradation A). 6 inches (for gradation B).
Slabs	NASA 1997	1 1/2 inches.
	Navy 1998	2 1/2 inches.
	VA 1996	1 inch.
Structures (Against Sides Above Drains)	NASA 1997	3/8 inch.
Structures (Against Sides)	Navy 1998	3 inches.
	OR DOT 1996	3 inches.
	Scotland DOT 1976	0.015 cubic meters.
Structures (General)	Army COE 1997	3 inches.
	Lake Oswego 1999	2 inches.

Purpose	Agency	Maximum Particle Size
Structures (General)	Navy 1998	3 inches.
	NM DOT 1994	2 inches.
	OR DOT 1996	2 inches.
	TX DOT 1993	A size that would interfere with compaction.
Trenches (General)	Army COE 1997	3 inches.
	FL DOT 1999	3/4 inch.
	Lake Oswego 1999	1 inch.
	Navy 1998	3 inches.
	WV DOT 1994	3 inches.
Trenches (Permeable Soil)	AASHTO 1984	1/2 inch (Course Aggregate). 3/8 inch (Fine Aggregate).
	IL DOT 1997	3 inches (for coarse aggregates). 3/8 inch (for fine aggregates).
Trenches (Sanitary/Storm Sewer Bedding)	VA 1996	1/2 inch.
Trenches (Select Soil)	Army COE 1997	3 inches or 1 inch per foot of pipe diameter.
	WI DOT 1996	6 inches. 1 inch (for pipe bedding).

Purpose	Agency	Maximum Particle Size
Trenches (Sewage Absorption)	Navy 1998	2 inches.
Trenches (Stabilization Of)	Lake Oswego 1999	3 inches.
Trenches (Under Paved Areas)	Navy 1998	2 1/2 inches.

Appendix C: Atterberg Limits Grouped by Purpose

Atterberg Limits Grouped by Purpose

Purpose	Agency	Max Liquid Limit	Max Plasticity Index
Bedding (General)	LA DOT 1992	Not specified.	Nonplastic (for sand, stone, and recycled portland cement concrete passing the no. 40 sieve).
	Navy 1998	Not specified.	6 (for material passing the 0.075 mm sieve).
Blankets (Plastic Soil)	LA DOT 1992	Not specified.	12 to 35.
Drains (Subsurface)	WI DOT 1996	25	6
Embankments (General)	Houston 1997	45.	12 to 20 (do not use a blend cohesive and granular soils to achieve this value).
	UT DOT 1994	Not specified.	Nonplastic.
Embankments (Granular)	IL DOT 1997	Not specified.	6 (for gravel). 4 (for crushed gravel, stone, and slag but waived if [%passing 0.075 sieve] / [%passing 0.425 sieve] is 0.60 or less).
	TX DOT 1993	45	15
Embankments (Nonplastic Soil)	LA DOT 1992	Not specified.	Nonplastic.
Embankments (Soil Above 8 ft Depth)	LA DOT 1992	Not specified.	20 (20 to 35 if treated with at least 6% lime).

Purpose	Agency	Max Liquid Limit	Max Plasticity Index
Embankments (Soil Below 8 ft Depth)	LA DOT 1992	Not specified.	35 (35 to 45 if treated with at least 10% lime).
Embankments (W/in 1000 ft Of Bridge End)	LA DOT 1992	Not specified.	10 to 20.
Foundations (General)	Houston 1997	Not specified.	Nonplastic.
	Navy 1998	35	12
General Fill	LA DOT 1992	Not specified.	20
	LANL 1997	Not specified.	Nonplastic.
	Navy 1998	35	12
	Scotland DOT 1976	90	65
General Fill (Select, Controlled)	LA DOT 1992	35	15
Geosynthetic Reinforcement (General)	FL DOT 1999	15	6
Geotextile Fabric Covering	IL DOT 1997	Not specified.	6 (for gravel). 4 (for crushed gravel, stone, and slag but waived if [%passing 0.075 sieve] / [%passing 0.425 sieve] is 0.60 or less).
Retaining Walls (Crib Type)	Navy 1998	35	12

Purpose	Agency	Max Liquid Limit	Max Plasticity Index
Retaining Walls (MSE Type)	DERS 1999	Not specified.	6
	Keystone 1994	40	10
	TX DOT 1993	Not specified.	6 (for gradation B).
Slabs	Navy 1998	35	12
Structures (Against Sides)	OR DOT 1996	Not specified.	6 (for material passing 0.425 mm sieve).
Structures (General)	NM DOT 1994	Not specified.	6 (for material passing No. 200 sieve).
	OR DOT 1996	Not specified.	6 (for material passing 0.425 mm sieve).
Trenches (Select Soil)	WI DOT 1996	25	6
Trenches (Under Paved Areas)	Navy 1998	35	12

Appendix D: Satisfactory Soils Grouped by Agency

Satisfactory Soils Grouped by Agency

Agency	Satisfactory Soil Description
	Not specified.
AASHTO 1984	Gravel, crushed gravel, crushed stone, crushed air-cooled blast-furnace slag, or crushed concrete.
	Porous, free-draining material consisting of sand, gravel, cinders, slag, or crushed stone.
	Cinders, sand, slag, gravel, or crushed stone.
	Hard, durable particles or fragments of crushed stone or natural gravel.
	Hard, durable, clean sand, gravel, crushed stone, or crushed slag.
Army COE 1997	Tough, durable particles of sand, gravel, or crushed stone.
	Clean, free draining sand or sand and gravel free from any objectionable coating.
	Clays, silty clays, or clayey silts. Silts and clays containing sand may be used if sufficiently impermeable and suitable for compacting with a tamping or rubber-tired roller.
	Well-graded sand, gravel, crushed gravel, crushed stone or crushed slag composed of hard, tough and durable particles.
	Clean, crushed, nonporous rock, crushed gravel, or uncrushed gravel.
	Washed sand.
	GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, SP-SM, SP-SC, CL, ML, CL-ML, CH, or MH.

Agency	Satisfactory Soil Description
CGSF 1988	Predominantly sand or sand and gravel.
FL DOT 1999	Naturally occurring materials such as gravel, or resulting from the crushing of parent rock, to include natural rock, slags, expanded clays and shales (lightweight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles.
	Free draining material.
Geostone	On-site dewatered, compatible selected fill and crushed stone.
Houston 1997	GW and SW. Well-graded gravels and sands, gravel-sand mixtures, crushed well-graded rock, little or no fines.
IL DOT 1997	Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand.
	Fine Aggregates: Sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand, granulated slag sand, crushed concrete sand, or construction and demolition debris sand. Course Aggregates: Gravel, crushed gravel, pit run gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone, or wet bottom boiler slag.
	Pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag, or crushed sandstone.
	Earth, stone, or gravel.
Keystone 1994	Site excavated soils.
	Clean crushed stone or crushed gravel.
LA DOT 1992	Sand, clam shell, or reef shell.
	Natural soil.

Agency	Satisfactory Soil Description
LA DOT 1992	Stone, recycled portland cement concrete, expanded clay, shell, gravel, crushed slag, or sand.
Lake Oswego 1999	Washed round rock.
	Native excavated material.
	Imported crushed rock or gravel or clean pit run gravel.
	Imported crushed rock.
	Imported crushed rock.
LANL 1997	Granular soil.
NASA 1997	Washed, uniformly graded mixture of crushed stone or crushed or uncrushed gravel.
	AASHTO M 145 Classification Groups A-1 (well graded mixture of stone fragments or gravel, coarse sand, fine sand and a nonplastic or feebly plastic soil binder, volcanic cinders without soil binder), A-2-4 and A-2-5 (gravel or coarse sand containing silt; fine sand containing nonplastic silt), and A-3 (fine beach sand and fine desert blow sand without silty or clay fines; stream deposited mixture of poorly graded fine sand, coarse sand, and gravel).
	Natural sand.
	Uniformly graded mixture of natural or crushed gravel, crushed stone, and natural sand.
	Sandy clay, sand, gravel, soft shale.
Navy 1998	GW, GP, SW, or SP.
	Clean sand, stone, or gravel fill.

Agency	Satisfactory Soil Description
Navy 1998	Clean crushed stone, crushed gravel, or uncrushed gravel. Clean concrete sand (for capillary water barrier underlay or for capillary water barrier not under slabs).
	GP, GM, GC, SP, SM, or SC.
	Sand, gravel, or crushed rock composed of tough, durable particles. ASTM D2321 Materials: Class I: Angular stone (including coral, slag, cinders, crushed stone, and crushed shells where available). Class II: Coarse sands and gravels including graded sands and gravels containing small percentages of fines, generally granular and noncohesive, wet or dry (this includes GW, GP, SW, and SP).
	GW, GP, GM, GC, SW, SP, SM, or SC.
	Clean crushed rock or gravel.
	GM, SM, or SC.
	GP, GM, GC, SP, or SM.
NM DOT 1994	Stone, crushed stone, crushed or screened gravel, caliche, or sand.
OR DOT 1996	Granular material consisting of crushed, durable rock.
	Granular material composed of crushed and/or uncrushed rock.
Scotland DOT 1976	Well graded crushed or uncrushed gravel, stone, rock fill, crushed concrete or slag or natural sand or a combination of any of these.
	Granular material.
Tensar 1997	Granular soil. Recycled concrete if high density polyethylene or polypropylene geogrid is used.
TX DOT 1993	Cohesionless materials, such as sand.

Agency	Satisfactory Soil Description
TX DOT 1993	Stone or lean concrete (only if backfilling an excavation in hard material resistant to erosion).
	Rock, loam, clay, or other materials.
	Granular material.
UT DOT 1994	Granular material.
VA 1996	Crushed stone or gravel.
WI DOT 1996	Sand, a mixture of sand with gravel, crushed gravel, crushed stone, or other broken or fragmented mineral material.
WV DOT 1994	Random material (a mixture of any or all of soil, granular material, or soft shale), hard shale, or rock. Preference given to granular soils.
	Crushed stone: particles of clean, hard, tough, durable rock, OR Gravel: particles of hard, durable rock, thoroughly clean and well graded, OR Slag: air cooled blast-furnace slag, reasonably uniform in density and quality.
	Random material (a mixture of any or all of soil, granular material, or soft shale).
	Random material (a mixture of any or all of soil, granular material, or soft shale) or crushed aggregate.

Appendix E: Unsatisfactory Soils Grouped by Agency

Unsatisfactory Soils Grouped by Agency

Agency	Unsatisfactory Soil Description
	Not specified.
AASHTO 1984	Soil that cannot be properly compacted, sod, and vegetable matter. Rocks, broken concrete, or other solid materials (where piling will be driven).
	Organic material, clay balls, or other deleterious substances.
Army COE 1997	OL, OH, and PT. Materials containing man-made fills, trash, refuse, backfills from previous construction, roots, organic matter, frozen materials, or contaminated materials.
	ML, MH, and CH for critical structures.
	Materials containing man-made fills, trash, refuse, backfills from previous construction, roots, organic matter, frozen materials, or contaminated materials.
	Materials containing brush, roots, sod or other perishable materials.
	Material containing thin, flat and elongated particles and/or soft, friable particles in objectionable quantities or material containing brush, roots, sod or other perishable materials.
CGSF 1988	Material containing clods, wood, or masonry debris, or other deleterious material.
DERS 1999	Material containing organic matter.
FAA 1991	Frozen material or material containing vegetable or organic matter, such as muck, peat, organic silt, or sod.
FL DOT 1999	Soil cement or lime stabilized backfill.

Agency	Unsatisfactory Soil Description
FL DOT 1999	Material containing unreasonable amounts of clay lumps, soft and friable particles, salt, alkali, organic matter, adherent coatings, and other substances not defined which may possess undesirable characteristics.
	Material containing muck, stumps, roots, brush, vegetable matter, rubbish, or other material that does not compact into a suitable and enduring roadbed.
Houston 1997	ML, CL-ML, MH, PT, OH, and OL. Materials that contain large clods, aggregates, debris, vegetation, waste or any other deleterious materials, hydrocarbons or other chemical contaminants. Materials that cannot be compacted to the required density due to either gradation, plasticity, or moisture content.
	Material containing lumps (greater than 6 inches), organic material, chemical waste or other contamination, and debris.
IL DOT 1997	Material containing an excess of soft and unsound particles and other objectionable matter.
	Sod, frozen material, or any material which by decay or otherwise, might cause settlement
Keystone 1994	Material containing debris. Highly plastic clays or organic soils.
	Highly plastic clays or organic soils.
LA DOT 1992	Large or frozen lumps, stones, roots, wood, and other foreign matter.
	Water saturated soils, organic matter, material not usable for foundation material, or material which will decay or produce subsistence in the soil such as stumps, roots, logs, or humus. Large amounts of fragmented reef shell.
Lake Oswego 1999	Material containing dirt, clay balls, and organic material.
	Material containing weeds, refuse, sticks, or other organic material which in the Engineer's opinion would compromise the integrity of the compacted trench.

Agency	Unsatisfactory Soil Description
LANL 1997	Material containing organic material or other deleterious materials.
MD DOT 1993	Frozen material.
NASA 1997	AASHTO M 145 Classification Groups A-2-6 and A-2-7(A-2-4 and A-2-5 soils containing plastic clay), A-4 (nonplastic or moderately plastic silty soil; fine silty soil), A-5 (diatomaceous or micaceous A-4 soils), A-6 (plastic clay soil; fine clayey soil), and A-7 (diatomaceous or micaceous A-6 soils), peat and other highly organic soil. Materials containing clay clods, debris, waste, frozen materials, or other deleterious matter.
Navy 1998	PT, OH, or OL. Material containing debris, refuse, roots, wood, scrap materials, vegetable matter, frozen material, or material having insufficient strength or stability to carry intended loads without excessive consolidation or loss of stability. Man-made fills, uncompacted backfills from previous construction, unsound rock or soil lenses, or other deleterious or objectionable material. PT, OH, or OL. Material containing debris, refuse, roots, wood, scrap materials, vegetable matter, frozen material, or material having insufficient strength or stability to carry intended loads without excessive consolidation or loss of stability. Large rocks, soft unsound particles, soluble particles, or other material which could damage the pipe or cause the backfill not to compact. Material containing debris, roots, wood, scrap material, vegetation, refuse, soft unsound particles, frozen, deleterious, or objectionable materials. Soft, spongy, highly plastic, or otherwise unstable material.
NM DOT 1994	Material free from organic matter, silt, clay balls, frozen matter, or other deleterious matter. Frozen material. Material containing rock, broken concrete, or other solid materials (where piling, utilities, or structures are to be built).
Scotland DOT 1976	Soluble sulphate content < 2.5 g/L.

Agency	Unsatisfactory Soil Description
Scotland DOT 1976	Material from swamps, marshes, and bogs; peat, logs, stumps, and perishable materials; material susceptible to spontaneous combustion; frozen material.
SHCE 1996	Material containing organic matter.
TX DOT 1993	Material containing wood, other extraneous material, frozen lumps, or large lumps that would not break down readily under compaction.
	Material containing organic or otherwise deleterious matter.
	Material containing organic or otherwise deleterious matter or unacceptable lumps of earth.
USBR 1999	PT, OL, OH. Material containing roots, stumps, limbs, vegetation, organic matter, ice, construction debris, scrap materials, refuse, man-made wastes, or chemical or hydrocarbon contamination.
VA 1996	Topsoil, frozen materials, construction materials, materials subject to decomposition, clods of clay, organic material, including silts, which are unstable, and inorganic materials, including silts, too wet to be stable.
WI DOT 1996	Material containing frozen lumps, wood, logs, stumps, brush, or other extraneous or perishable material.
WV DOT 1994	Materials which cannot be satisfactorily placed and compacted to a stable and durable condition. Sod, trash, organic substances beyond the allowed percentage, or muck. Soil that contains excessive moisture. Soil containing stumps and spongy or frozen soil. When piles driven: soil containing rock.
	Material containing frozen lumps, wood, or other extraneous material.
	Crushed stone: particles with adherent coatings. Slag: slag containing dirt or other objectionable matter.

Appendix F: Gradations Grouped by Agency

Gradations Grouped by Agency

Agency	Gradation
	Not specified.
AASHTO 1984	Course Aggregate (AASHTO M 43, size No. 89): mm % 12.5 100 9.5 90-100 4.75 20-55 2.36 5-30 1.18 0-10 0.300 0-5 Fine Aggregate (AASHTO M 6): mm % 9.5 100 4.75 95-100 1.18 45-80 0.300 10-30 0.150 2-10
	Uniformly graded.
	AASHTO M 43, size No. 467: mm % 50 100 37.5 95-100 19 35-70 9.5 10-30 4.75 0-5
	AASHTO M 43, size No. 357: mm % 63 100 50 95-100 25 35-70 12.5 10-30 4.75 0-5
	3 in 100% no. 4 20-50% no. 200 0-10%

Agency	Gradation
Army COE 1997	4.75 mm no more than 2%
	Grading curves shall not exhibit abrupt changes in slope denoting skip grading, scalping of certain sizes, or other irregularities which would be detrimental to the proper functioning of the filter.
	0.075 mm less than 5% 0.020 mm not more than 2%
	25 mm not less than 95% 0.075 mm not more than 10%
CGSF 1988	Not more than 20% passing the No. 200 sieve.
DERS 1999	6 inch 100% 3 inch 10-75% no. 200 0-25% 4 inch 100% no. 40 0-60% no. 200 0-15%
FL DOT 1999	19 mm 100% 12.5 mm 90-100% 9.5 mm 40-70% 4.75 mm 0-15% 2.36 mm 0-5%
	90 mm 100% 19 mm 70 to 100% 4.75 mm 30 to 100% 0.425 mm 15 to 100% 0.150 mm 5 to 65% 0.075 mm 0 to 15%
	A gradation that minimizes voids between particles.
Houston 1997	D60/D10 greater than 4% no 200 not greater than 5%

Agency	Gradation
IL DOT 1997	FA 6 4.75 mm 92±8 0.150 mm 20±20 0.075 mm 6±6
	CA 6 CA 10 37.5 mm 100 -- 25 mm 95±5 100 19 mm -- 95±5 12.5 mm 75±15 80±15 4.75 mm 43±13 50±10 1.18 mm 25±15 30±15 0.075 mm 8±4 9±4
	Course Aggregates: CA 18 75 mm 100 25 mm 95±5 4.75 mm 75±25 1.18 mm 55±25 0.300 mm 10±10 0.075 mm 2±2 Fine Aggregates: FA 1 FA 2 9.5 mm 100 100 4.57 mm 97±3 97±3 1.18 mm 65±20 65±20 0.300 mm 16±13 20±10 0.150 mm 5±5 5±5 0.075 mm 2±2 2±2
	FA 1 FA 2 9.5 mm 100 100 4.57 mm 97±3 97±3 1.18 mm 65±20 65±20 0.300 mm 16±13 20±10 0.150 mm 5±5 5±5 0.075 mm 2±2 2±2
Keystone 1994	2 inch 100-75% 3/4 inch 100-75% No. 4 100-20% No. 40 0-60% No. 200 0-35%
LA DOT 1992	Extensive gradation requirements that are too lengthy and detailed to include in this database.

Agency	Gradation
LA DOT 1992	Sand No. 4 75% No. 200 15% Shell No. 200 15%
Lake Oswego 1999	Well graded from course to fine with no more than 8% by weight passing the No. 200 sieve.
	Graded from 1.5 inches to 3/4 inches.
	Less than 8% passing the No. 200 sieve.
	3 inch more than 90% 1 inch more than 50% no. 200 not more than 20%
NASA 1997	9.5 mm 100% 0.150 mm 2-10%
	37.5 mm 100% 4.75 mm not more than 5%
Navy 1998	Shall contain sufficient fines to ensure proper compaction.
	Underlay: 3% passing 0.075 mm sieve.
	Class I: Sizes from 0.25 to 1.5 in. Class II: Max size of 1.5 in.
	0.075 mm 25%
	50 mm 100% 12.5 mm 0%

Agency	Gradation
Navy 1998	2 1/2 in 100% No. 4 40-85% No. 10 20-80% No. 40 10-60% No. 200 5-35% (10% for crib wall)
	a. Perforated or slotted wall pipe: Type I. b. Open joint pipe: Type I and Type II (i.e. two soils used as a combination). c. Blind or french drains: Type II. c. Any pipe used with filter fabric: Type I, or Type II. Type I Type II 37.5 mm -- 100 25.0 mm -- 90-100 9.5 mm 100 25-60 4.75 mm 95-100 5-40 2.36 mm -- 0-20 1.18 mm 45-80 -- 0.300 mm 10-30 -- 0.150 mm 0-10 --
NM DOT 1994	No. 200 25%
OR DOT 1996	75 mm 100% 9.5 mm 0 - 80% 425 mm 0 - 40% 150 mm 0 - 10% 75 mm 0 - 6%
	50 mm 100% 12.5 mm 50 - 80% 4.75 mm 35 - 70% 425 mm 15 - 35% 150 mm 0 - 15%
Scotland DOT 1976	10 mm up to 100% 5 mm not more than 85% 0.6 mm not more than 45% 0.075 mm not more than 5%
	125 mm not less than 95% 75 mm at least 90% 0.075 mm not more than 10%

Agency	Gradation
Tensar 1997	2 inch 100-75% 3/4 inch 100-75% no 4 100-20% no 40 0-60% no 200 0-35%
TX DOT 1993	Less than 20% passing 3 inch sieve.
	Gradation A: 3 inches 100% No. 40 0-60% No. 200 0-15% Gradation B: 6 inches 100% 3 inches 75-100% No. 200 0-15% 15-25% (Alternative)
	A gradation that permits thorough compaction.
VA 1996	Graded from 25 mm (1 inch) to No. 4.
	Graded from 13 mm (1/2 inch) to No. 4.
WI DOT 1996	75 mm 100% 4.75 mm not less than 25% Of all material passing 4.75 mm sieve: 0.075 mm not more than 15%

Agency	Gradation
WI DOT 1996	150 mm 100% 75 mm not less than 85% 4.75 mm not less than 25% Of material passing 4.75 mm sieve: Grade 1: 4.75 mm 100% 0.425 mm not more than 75% 0.150 mm not more than 15% 0.075 mm not more than 8% Grade 2: 4.75 mm 100% 0.425 mm - 0.150 mm not more than 30% 0.075 mm not more than 15%
WV DOT 1994	50 mm 100% 1.18 mm 0-5%

Appendix G: Other Requirements Grouped by Agency

Other Requirements Grouped by Agency

Agency	Other Requirements
	Not specified.
DERS 1999	Angle of internal friction not less than 34 degrees.
FL DOT 1999	Organic material: not more than 2% by weight. pH from 6 to 10.
	Los Angeles Abrasion: maximum loss 45%. Soundness (Sodium Sulfate): maximum loss 12%. Flat or elongated pieces: maximum 10%.
IL DOT 1997	Bearing Ratio not less than 80 (for embankment fill only except when crushed gravel, crushed stone, or crushed slag used). Na2SO4 Soundness 5 Cycle: maximum loss 25%. Los Angeles Abrasion: maximum loss 45%.
LA DOT 1992	pH from 5.5 to 8.5.
	Organic content of 4% or less.
	Organic content of 2% or less. Silt content of 60% or less.
	Organic content less than 5%. Silt content of 60% or less.
Navy 1998	Coefficient of permeability shall be a minimum of 0.01-1 mm/sec (0.002-0.2 ft/min).
Tensar 1997	pH from 5 to 9 (waived when high density polyethylene or polypropylene geogrid is used).
TX DOT 1993	Angle of internal friction not less than 34 degrees at 95% of Da density (only for Alternative Type B).

Agency	Other Requirements
TX DOT 1993	Bar Linear Shrinkage not greater than 2.
WV DOT 1994	Crushed stone: Percentage wear not to exceed 40. Soundness loss not to exceed 12. Percent by weight maximums: thin or elongated pieces 5%, shale 1%, coal and other lightweight deleterious material 1.5%, friable particles 0.25%.
	Organic content shall be less than 7.5% by weight.

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