# Beneficial Use of Dredged Materials in Great Lakes Commercial Ports for Transportation Projects

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16. Abstract:

This report describes an effort to facilitate beneficial use of dredged materials (DM) from Great Lakes ports and harbors as an alternative construction material in transportation-related earthwork applications. The overall objective is to link together the following components: 1) identify applications for use of DM in transportation-related projects, 2) summarize required geotechnical properties in specific transportation applications, 3) identify available geotechnical test methods to determine those properties, 4) identify specific values of required geotechnical material properties for specific uses, and 5) identify locations within the Great Lakes region where dredged materials meeting these specifications may be sourced. This report pulls together available information on potential applications for the use of DM in transportation earthwork projects, the required geotechnical properties of materials according to federal and state construction specifications, and the geotechnical laboratory and field test methods available to determine these properties. Representative geotechnical properties of DM from select Great Lakes locations are synthesized from available literature and the results of laboratory tests conducted on DM sampled from the Milwaukee confined disposal facility (CDF). Results are evaluated within the framework developed above to assess the suitability of unamended DM from each location for beneficial use in transportation construction. Based on the information obtained, material potentially sourced from these locations has limited direct use in its raw or unamended form. Review of general sediment types in harbors throughout the region, however, indicates that there may be large potential for beneficial use of DM because the sediment type from numerous harbors in the region is predominantly coarse-grained. Fine-grained materials are also a potential source of material if amended or stabilized with other materials (e.g., fly ash). Future effort should focus on laboratory evaluation of stabilized fine-grained DM, detailed field characterization of the physical properties at DM sources throughout the region, and dissemination and outreach to promote the concept of beneficial use of dredged materials in transportation construction.

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## Final Report

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May 2014

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# Disclaimers

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# Chapter 1: Introduction

## 1.1 Scope

This chapter briefly introduces the problems and opportunities associated with dredged material (DM) management in the Great Lakes region and historical options for beneficial use of DM. The overall objective of the project and the structure and scope of this report are summarized.

## 1.2 Statement of Problem

Dredging is an indispensable part of maintaining marine transport and supporting the freight transport system by enlarging or deepening existing navigation channels and harbors. Hundreds of millions of cubic yards of sediment are dredged from U.S. ports, harbors, and waterways each year. Safe and economical disposal of the huge volume of DM is a significant and pressing issue.

Many existing confined disposal facilities (CDFs) serving ports in the Great Lakes region are at or near capacity (Great Lakes Commission, 2001). High costs plus limited new site availability make prospects for new or expanded disposal capacity increasingly unlikely. According to the US Army Corps of Engineers (USACE), at least six of the Great Lakes largest cargo-handling ports – Duluth/Superior, Calumet Harbor, Saginaw, Toledo, Lorain and Cleveland – are in “critical” status, meaning that DM management issues could “severely restrict channel availability within five years.” Another six ports – Green Bay, Sheboygan, Port Washington, Milwaukee, Rouge River and Ashtabula – have “pressing” needs that could restrict channel availability in ten years.

Implications of these restrictions to freight movement in the North American mid-continent are serious. Some 175 million to 200 million tons of primarily bulk commodities – including iron ore, coal, stone, petroleum products, chemicals and grain – are moved annually on the Great Lakes St. Lawrence Seaway system. The marine mode has been well documented as the most fuel efficient, least air toxic and safest mode for movement of this cargo, and Great Lakes marine transportation supports some of North America’s most important core industries including steel manufacturing, automotive, construction and agriculture. For many Great Lakes bulk cargo movements, the sheer volume of material precludes shifts to other surface transportation modes.

Given the declining placement capacity, disposal of non-toxic DM in the historic sense, as solid waste, is no longer feasible as an ongoing management practice in the Great Lakes. Use or recycling of material suitable for beneficial use (BU) is emerging as a potentially practical approach to sustainable DM management in the region. One factor favoring increased BU is the improving physical quality of the material; as toxic sediments in areas of concern (AOCs) and other waterways with industrial or otherwise toxic legacies have been remediated in recent decades. As toxic discharges have been eliminated, DM caused by natural sedimentation has become cleaner and more acceptable for beneficial use. Beneficial use of DM alone or in mixtures with other materials or managed byproducts could have a major impact solving the declining disposal capacity.

## 1.3 Objective

This project focuses on beneficial use of DM as an alternative material for earthwork construction applications in the transportation sector (e.g., embankments, pavement base, etc.). The long term objective of the effort is to contribute to sustainable construction by facilitating use of DM instead of natural mined materials. The immediate objective, as described here and summarized in Figure 1.1, is to produce a set of guidelines that explicitly links together: 1) applications for the use of DM as construction materials in transportation-related earthwork projects, 2) required geotechnical properties of materials for specific construction applications, 3) geotechnical laboratory and field test methods available to determine these properties, 4) specifications (values) of these properties required for specific transportation-related projects, and 5) locations within the Great Lakes from which dredged materials having properties meeting these specifications may be sourced. The project is intended to build upon existing and more general frameworks for beneficial use of DM from the Great Lakes region (Great Lakes Commission, 2004) but within the specific context of using DM in the transportation construction sector. Emphasis is placed entirely on suitability in terms of physical characteristics. Suitability in terms of toxicity or environmental characteristics of the material is assumed.

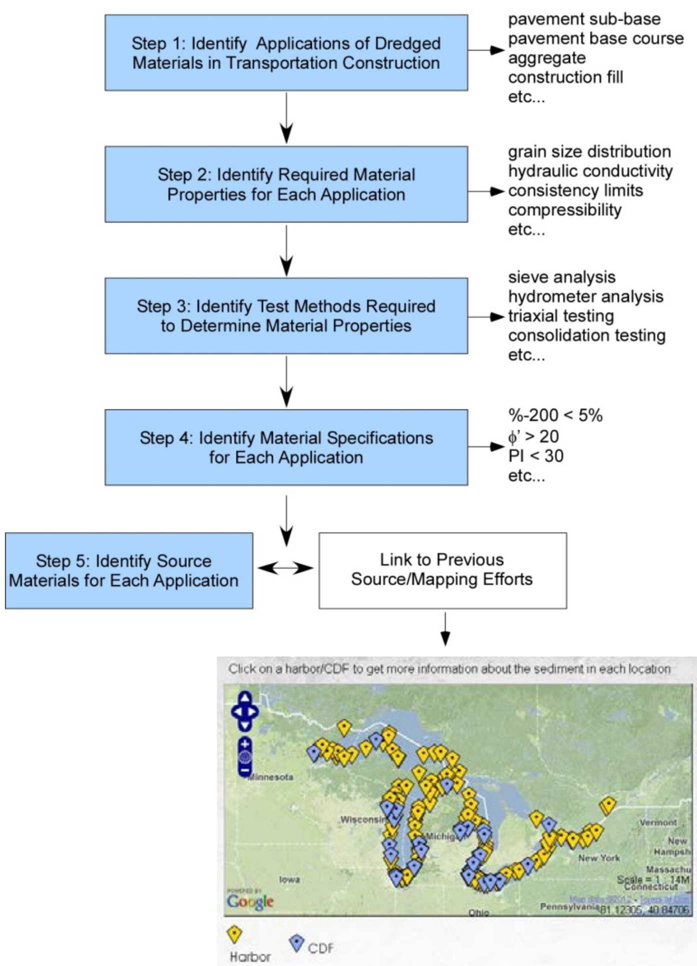



Figure 1.1 Summary of project scope for beneficial use of dredged materials in the Great Lakes region (map from http://www.glc.org/rsm/mapholder.html)

## 1.4 Structure

This report is organized into six interrelated chapters.

Chapter 1: Introduction. This chapter provides a brief introduction to the project and its long- and short-term goals. This includes description of historical and current options for management of DM in the Great Lakes regions, a summary of the framework for the project, and a summary of the organization and scope of the report.

Chapter 2: Background. This chapter provides basic information regarding DM management and discusses disposal as a general method of DM management. An introduction to beneficial use of DM is provided.

Chapter 3: Geotechnical Properties Required for Transportation Construction Applications. This chapter provides a summary of general geotechnical characteristics of materials required in different applications of roadway construction, along with the specific physical and engineering properties required.

Chapter 4: Geotechnical Properties and Test Methods. This chapter identifies the physical and engineering characteristics required for consideration of DM in various transportation applications. Tests and specifications are synthesized from information available from ASTM International (ASTM), the American Association of State Highway and Transportation Officials (AASHTO) and the Wisconsin Department of Transportation (WisDOT).

Chapter 5: Properties of Dredged Materials from Select Great Lakes Locations. This chapter contains a summary of geotechnical analysis and properties of DM obtained from select harbors and CDFs within the Great Lakes region. Geotechnical testing data are synthesized for select harbors using reports available in the literature (Calumet, Indiana, Waukegan and West-arms Burns) and from laboratory tests conducted at the University of Wisconsin-Madison (UW) for samples obtained directly from a confined disposal facility (CDF) in Milwaukee, WI.

Chapter 6: Implementation of a Beneficial Use Framework. This chapter describes the process and results of making the connection between DM sources and transportation sector applications based on the geotechnical properties of the materials identified in Chapter 5.

# Chapter 2: Background

## 2.1 Scope

DM management options including open-water disposal, confined disposal, and beneficial use are summarized. Specific categories for beneficial use of DM and relative examples are described. Discussion in this chapter has been synthesized from the literature.

## 2.2 Dredged Material Management

Three general management alternatives may be considered for DM: open-water disposal, confined disposal, and beneficial use. Open-water disposal is the placement of DM in rivers, lakes, estuaries, or oceans via pipeline or release from hopper dredges or barges. Confined disposal is placement of DM within dikes located near shore or in upland disposal facilities via pipeline or other means. Beneficial use involves the placement or use of DM for some productive purpose.

### 2.2.1 Open Water Disposal

Open water disposal has historically been one major way of managing DM, however several Great Lakes states prohibit open lake disposal. To assess the suitability of open water disposal, the following aspects should be considered. Evaluation of site characteristics is a primary step to determine the suitability of the management approach. Site characteristics include environmental aspects (e.g., water depth and wave climate), physical, chemical and biological factors (e.g., sediment condition, habitat types), and site capacity affecting the operation and efficiency of disposal.

Site specification should be considered under the appropriate state and federal regulations such as the Clean Water Act, which establishes sequential review of a proposed project, the first step of which is avoidance of adverse impacts to the aquatic environment through an evaluation of practicable alternatives that would have less impact on that environment. Table 2.1 summarizes several aspects of laws and regulations for open water disposal in the Great Lakes Region.

### 2.2.2 Confined Disposal

The appropriate disposal of DM in confined disposal facilities (CDFs) is an important issue around the Great Lakes. Approximately two million cubic yards of contaminated sediments is dredged annually from the Great Lakes. They must be placed in CDF's unless processed in some manner such that the contaminants do not re-enter the water or environment. Because polluted materials are not suitable for open water disposal, they may be placed in CDFs. The significant difference in site characteristics between open water disposal and confined disposal concentrates on two facets: one is real estate consideration, the other is safety. Generally speaking, CDFs represent a substantial economic investment, especially when considering long term capacity. Sites are normally visible to the public and are viewed as a competing interest for land use, especially in coastal areas where there is intense pressure for both development and preservation of lands. From the aspect of safety, unlike in the case of open water disposal, contaminant pathways are wider in confined disposal, and include but not limited to volatilization of contaminants (e.g., from sediment to air) and odor.

### 2.2.3 Beneficial Use

The frequency of beneficial use in the Great Lakes Region is under 18 percent. However, around 2 million cubic yards of sediments dredged form Great Lakes annually can be considered as uncontaminated material, which means the beneficial use has great potential and could have significant advantages compared with other management options.

Table 2.1 Laws and Regulations for Open Water Disposal in Great Lakes Region
(Source: Great Lakes Commission)

| State | Permit Open Water Disposal | Law/Regulation |
|---|---|---|
| IL | Yes | Must comply with state water quality standards; negative impacts are to be mitigated. |
| IN | Yes | Must comply with state water quality standards; contaminated sediments are prohibited. |
| MI | Yes | Must comply with state water quality standards; contaminated sediments are prohibited. |
| MN | No | Only beneficial use projects that result in an improvement of natural conditions such as habitat enhancement and creation are permitted |
| NY | Yes | Must follow state management guidelines for sediments classified under specific material categories. |
| OH | Yes | Must comply with state water quality standards; state wants to gradually phase-out open water disposal. |
| PA | Yes | Must comply with state water quality standards |
| WI | No | Open water disposal is a last resort; direct legislative authority is needed. |

## 2.3 Types of Beneficial Use

Beneficial use of DM can take various forms depending on its geotechnical and chemical characteristics. For uncontaminated DM, fine-grained material can be used to form construction materials after stabilization with amendments such as fly ash and lime. Sands can be used as reinforced fill in Mechanically Stabilized Earth (MSE) retaining walls, or considered as raw material for building or improving fish and wildlife habitat. Gravel and rocks can be used as base or sub-base aggregate for pavement and roadway construction. Beneficial use is also acceptable for contaminated soils, such as using them in landfill capping applications. The USACE indicates more specific beneficial use category based on sediment types (Table 2.2), as summarized in the following.

Table 2.2 Beneficial Use Options for Dredged Materials (Source: USACE)

| Category | Examples of Beneficial Use Activities | Dredged Material Sediment Type | | | | |
|---|---|---|---|---|---|---|
| | | Rock | Gravel & Sand | Stiff Clay | Silt/Soft Clay | Mixture[1] |
| Agriculture/ Product Uses | Aquaculture | | | x | x | x |
| | Construction Materials | x | x | x | x | x |
| | Decorative Landscaping Products | | x | x | x | x |
| | Topsoil | | | | x | x |
| Engineering Uses | Beach Nourishment | | x | | | |
| | Berm Creation | x | x | x | | x |
| | Capping | | x | x | | x |
| | Land Creation | x | x | x | x | x |
| | Land Improvement | x | x | x | x | x |
| | Replacement Fill | x | x | | | x |
| | Shore Protection | x | x | x | | |
| Environmental Enhancement | Fish& Wildlife Habitats | x | x | x | x | x |
| | Fisheries Improvement | x | x | x | x | x |
| | Wetland Restoration | | | x | x | x |

Note: 1. a mixture of materials such as boulders lumps of clay, gravel, organic matter, and shells, with varying densities.

### 2.3.1 Habitat Restoration and Development

DM can be used for creating, enhancing and restoring ecosystem habitats. A variety of material types including rock, gravel, sand, silt, clay and mixtures can be used as raw material for habitat restoration. However, contaminated DM is unsuitable for this alternative unless proper remediation methods to improve DM's chemical and biological properties are followed.

The United States has a long history of using DM for habitat restoration. DM has been used in the construction of submerged gravel bar habitats since 1988. In 2010, The National Oceanic and Atmospheric Administration (NOAA) engaged in ecosystem restoration and sediment management in the Louisiana-Mississippi Gulf Coast. In the Great Lakes region, the Cat Island (located near the southern end of Green Bay) restoration project is designed to enhance and restore wetland habitat and three islands that were eroded away during high water levels.

### 2.3.2 Beach Nourishment

Beach Nourishment involves the use of DM (primarily sandy material) to restore beaches prone to erosion. Compared with other beneficial use alternatives, beach nourishment is a widely used option, especially in the Great Lakes region. According to the Great Lakes Commission (GLC), 17% of sediments dredged form Great Lakes annually is used as beach Nourishment. Thirty-one harbors located around the Great Lakes have included beach nourishment as a primary DM disposal method (Zande, et al, 1994). From 1987 to 1988, approximately 1.5 million cubic yards of gravelly sand was used for constructing the 72-acre North Point marina on the Illinois shore. As of 1999, 40,000 cubic yards of DM was placed around Ohio and Pennsylvania harbors.

### 2.3.3 Parks and Recreation

Recreational activates require corresponding facilities, such as trails for hiking and water access for fishing. All soil types can be considered for beneficial use in this context. In 2012, approximately 100,000 cubic yards of dredged material from the Havre de Grace Yacht Basin in Maryland, for example, was used for building a walking trail on top of the area's dikes in a recreational area.

### 2.3.4 Agriculture, Forestry, Horticulture and Aquaculture

DM can be used to replace eroded topsoil, elevate the ground surface, or improve the physical and chemical characteristics of soils. Physical properties (e.g., gradation, texture and water content) significantly affect suitable use of DM in such applications. For instance, vegetables grow best on sandy loam soils of good texture, drainage, and aeration. Therefore, sandy or silty DM rather than clay is preferred for this beneficial use option. On the other hand, based on consideration of the chemical and biological aspects, organic matter is another important component in DM and can provide proper conditions to enhance the soils. In contrast, high contaminant (e.g., heavy metal) levels are undoubtedly harmful for such applications. Planning considerations, site locations, weed infestation potential, and possible salinity problems must also be considered before deciding upon the suitability of a specific DM for agricultural application. In 1979, about 500 acres of the Old Daniel Island Disposal Site in South Carolina had been successfully truck-farmed, and other parts of the site are planted in soybeans.

### 2.3.5 Strip-Mine Reclamation and Solid Waste Management (Landfill Capping)

The most important characteristic of DM for this beneficial use option is low permeability. There are several examples of recent success in this application. In the Bark Camp Mine Restoration Project in Pennsylvania, DM blended with alkaline-activated coal ash was used as manufactured fill for abandoned mine reclamation with positive environmental benefits. In over five years of surface water and ground water monitoring, there was detection of semi-volatile or volatile organic compounds, pesticides, PCBs, dioxins. DM can also be used for daily cover, capping and closure of landfills. Newer mine-land reclamation case studies have shown that DM, especially the fine material provides for better vegetation recovery than existing mine tailings material alone.

### 2.3.6 Construction and Industrial Development

DM can be used as raw material for manufacture of concrete, asphalt, bricks and other construction materials. By adding fly ash or other stabilizers, the physical and chemical properties of raw DM can be improved to fulfill the requirements of these construction materials. Coarse-grained DM can be used as raw material for asphalt, as fill material, or to improve the physical properties of soils for construction of buildings, roads and bridge abutments. DM with a high percentage of clay can be mixed with cement and stabilizer to create cement-like bricks. DM can be dewatered, mixed with shale fines, extruded into pellets and fired in a kiln, which can be used as raw material for the manufacture of lightweight concrete, thus reducing the need for extractive mining operations.

## 2.4 Beneficial Use in Transportation Construction

Potential applications for beneficial use of DM in construction of transportation facilities include use in pavement structures (e.g., embankment, subgrade, base and sub-base), structural fills, and backfills behind retaining walls such as Mechanically Stabilized Earth (MSE) walls. In 1999, the New Jersey Department of Transportation (NJDOT) constructed two roadway embankments to study the feasibility of beneficially reusing Stabilized Dredged Material (SDM). Construction of a parking lot for the Jersey Garden's Mall in New Jersey used approximately 600,000 cubic yards of SDM as structural fill.

Determining the efficacy of beneficial use in transportation construction requires understanding of geotechnical and structural elements of common transportation systems. Barriers to optimal use of DM for beneficial use include an inconsistency between screening metrics (e.g., gradation) and the way they can be applied (Brandon and Price, 2007). For example, fine-grained soil such as clay is generally not suitable for backfills in MSE walls due to its low permeability and strength. However, fine-grained material can potentially be used as geotube infill or regular fill in raising the elevation of depressed areas and in generating topsoil for landscaping purposes. Identifying relevant material characteristics is also important. Specific geotechnical properties need to be considered for essentially all earthwork applications in the transportation sector (e.g., grain size distribution, Atterberg limits, compaction characteristics). Pavement design requires assessment of resilient modulus and durability characteristics (durability to freeze-thaw and wet-dry cycles). Design of structural fills or wall backfills requires consideration of shear strength affecting slope stability and hydraulic conductivity affecting drainage. The following chapter summarizes relevant geotechnical properties such specific applications.

# Chapter 3: Geotechnical Properties Required for Transportation Construction Applications

## 3.1 Scope

This chapter provides a summary of geotechnical properties required for five representative transportation projects, including earth embankments, pavement base, sub-base, and subgrade, and backfill material for Mechanically Stabilized Earth (MSE) walls. Information in this chapter is synthesized from American Association of State Highway and Transportation Officials (AASHTO) and Wisconsin Department of Transportation (WisDOT) design guidelines.

## 3.2 Embankments

According to the American Association of State Highway and Transportation Officials (AASHTO), a roadway embankment is a raised structure of soil, soil-aggregate or rock. According to the Wisconsin Department of Transportation (WisDOT) Construction and Materials Manual (CMM), the success of an constructed embankment to support a pavement structure depends upon proper preparation of the foundation, use of suitable materials, and proper material placement and compaction. Particle size distribution (gradation) and Atterberg limit indices (plasticity) can be used to determine soil classification (suitable material) according to either Unified Soil Classification System (USCS) or AASHTO standards. The Proctor compaction test is recommended to determine the suitability of a specific material to be used as structural material in one of the different layers of road construction (Siham, et al, 2008). Therefore, for constructing roadway embankments, suitable materials should fulfill the relative requirements from the specification of AASHTO and Departments of Transportation (DOTs) in various states, especially with regard to physical properties (e.g. gradation) and engineering properties (e.g., compaction).

AASHTO provides specific requirements for soil used as embankment fill. Course-grained soils with low plasticity (plasticity index PI less than 10) or non-plastic soils is a primary preferred option, including materials classified in the A-1, A-2-4, A-2-5 or A-3 groups (Table 3.1). Course grained soils with relatively high plasticity (PI above 11) , such as A-2-6 and A-2-7 groups, and fine grained soils (silty soils and clayey soils), such as A-4, A-5, A-6 and A-7 groups can also be considered as an alternative when materials in former groups are not available. The WisDOT CMM also indicates that silty soils and clays are suitable for embankments when dried to optimum moisture. DM consisting of primarily fine-grained soils (as in most CDFs and harbors) is thus potentially applicable as embankment material if simple soil classification is considered the sole basis for suitability.

Compaction is necessary during the construction of an embankment and extremely important for ensuring slope stability and decreasing deformation and long-term settlement. Various DOT specifications provide detailed information about field compaction methods, required thickness and width of compaction layers (lifts), and appropriate compaction equipment for various material types. Proctor (compaction) tests are used to determine optimum water content and maximum dry density. Excessive or insufficient water content can both affect embankment performance negatively.

In 1998, the New Jersey DOT (NJDOT) established a project to assess the suitability of using DM in roadway construction. The project involved the construction of two roadway embankments and an access road using stabilized DM in Elizabeth, New Jersey. From this demonstration project, through using stabilized DM, embankment performance in terms of slope deformations and settlement characteristics was satisfactory according to NJDOT specifications.

### 3.3 Pavement Base and Subbase

Discussion of pavement sub-base and base course construction requires distinction between flexible pavements and rigid pavements. Flexible pavements usually consist of a prepared roadbed (subgrade), sub-base, base and surface course. In contrast, rigid pavements generally include subgrade, sub-base and a pavement slab. The sub-base is located between the subgrade soil and base course (in flexible pavements) or pavement slab (in rigid pavements). Sub-base is not necessary for the pavement if the subgrade soil is of relatively good quality, but can be an economical solution for construction of pavement over poor soils. According to AASHTO, the upper limit of grain size passing #200 sieve must be less than 25%. In other words, granular material is primary option for subbase material. Water content should be equal to or slightly below optimum to ensure the design density, and thus dewatering of DM is anticipated to be a crucial issue for this beneficial use option. In addition to a structural part of pavement, sub-base can be also used to prevent migration of fine-grained subgrade soils into the base course by using dense graded materials, minimize frost action effects by using materials that are not susceptible to frost action, and prevent free water accumulation in the pavement structure by using relative free draining materials.

Unlike the sub-base course, a pavement base course is only applicable in a flexible pavement structure. A base course usually consists of aggregate such as crushed stone or slag, crushed gravel and sand, or a combination of these materials. Since the major function of base is structural support, the requirements for strength, plasticity and gradation are more stringent than for sub-base materials. From the aspect of gradation, requirements for the base course are typically the same as for subbase course materials (i.e., coarse grained soils are suitable.)

DOTs have developed specifications for stabilization of base or subbase course materials. For example, Texas DOT has Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures. Beneficial use of DM can thus be potentially broadened by using stabilizing amendments if the raw DM cannot meet the requirements of base or sub-base course materials.

Table 3.1 Classification of Soils and Soil-Aggregate Mixture

| General Classification | Granular Materials[1] | | | | | | | Silt-Clay Materials[2] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group Classification | A-1 | | A-3 | A-2 | | | | A-4 | A-5 | A-6 | A-7 | |
| | A-1-a | A-1-b | | A-2-4 | A-2-5 | A-2-6 | A-2-7 | | | | A-7-5 | A-7-6 |
| Sieve analysis: | | | | | | | | | | | | |
| 2.00 mm (No.10) | 50 max | - | - | - | - | - | - | - | - | - | - | - |
| 0.425 mm (No. 40) | 30 max | 50 max | 51 min | - | - | - | - | - | - | - | - | - |
| 75 µm (No. 200) | 15 max | 25 max | 10 max | 35 max | 35 max | 35 max | 35 max | 36 min | 36 min | 36 min | 36 min | 36 min |
| Atterberg Limits | | | | | | | | | | | | |
| Liquid Limit | - | | - | 40 max | 41 min | 40 max | 41 min | 40 max | 41 min | 40 max | 41 min | 41 min |
| Plastic Index | 6 max | | NP | 10 max | 10 max | 11 min | 11 min | 10 max | 10 max | 11 min | 11 min | 11 min |
| Usual types of materials | Stone fragments, gravel and sand | | Fine sand | Silty and Clayey gravel and sand | | | | Silty soils | | Clayey Soils | | |
| General rating as subgrade | Excellent to Good | | | | | | | Fair to poor | | | | |

Note: 1, 35 Percent or Less Passing 75 um; 2, More Than 35 Percent Passing 75 um

Source: AASHTO Designation

## 3.4 Pavement Subgrade

The pavement subgrade is that portion of the earth roadbed which, after having been constructed to reasonably close conformation with the lines, grades, and cross-sections indicated on plans, receives the base or surface material. According to AASHTO, the subgrade is regarded as a prepared and compacted soil immediately below the pavement system and extending to such depth that will affect the structural design. Subgrade as one of substructure components is located between embankment and sub-base or base.

In addition to soil classification requirements, the definitive material property used to characterize subgrade soils for pavement applications is the resilient modulus ($M_R$). To improve the general reliability of the road structure, other soil properties, such as compression, permeability (drainage) and freeze and thaw, are also necessarily considered.

According to AASHTO soil classification (Table 3.1), granular materials are more proper than silt-clay material as subgrade. The Group Index (GI) can be used for evaluating the suitability from specific information obtained as part of the soil classification:

$$GI = (F-35)\,[0.2 + 0.005\,(LL-40)] + 0.01\,(F-15)\,(PI-10)$$

F = percentage passing No.200 sieve
LL = Liquid Limit, and
PI = Plasticity Index

Coarse soils with low F and PI have smaller GI than fine grained soils, which means these groups (A-1, A-2 and A-3) of soils are the primary choice as subgrade materials. Subgrade materials play an important role in their resistance to deformation under load. The resilient modulus indicates a basic material property which can be used in mechanistic analysis of multi-layered systems for predicting roughness, cracking, rutting and faulting (AASHTO Guide for Design of Pavement Structure, 1986). Its values are closely related to the various properties of the compacted layer of the subgrade soil.

Compressibility and expansion are other important properties in subgrade soil considerations. In general, fine-grained soils tend to be more susceptible to compressions or expansion. When fine-grained soils are subject to compression and rebound under cyclic load, adequate protection must be provided since small movements of this type may be detrimental to the pavement base and wearing course. Coarse-grained soils, on the other hand, exhibit much less tendency toward compressibility or expansion, which is one of reason why such soils are generally more suitable as subgrade materials. Compressibility and expansion is not only influenced by internal factors, such as soil structure and grain shape, but also by other external factors, such as weather conditions, which may change the water content in subgrade soils. To reduce the undesirable results caused by compression or expansion, one solution is to cover these soils with a greater thickness of selected materials. This method has limited effects when considering beneficial use of DM. Another is to stabilize unsuitable soils with cement, fly ash, or lime.

Organic and frost-susceptible soils are not suitable as subgrade materials. The problem with high organic material is its extremely compressible nature and is exacerbated when deposits are heterogeneous. Organic content can be an appreciable component of DM from some CDFs and harbors. Therefore, it is necessary to consider this characteristic when evaluating the applicability of DM in subgrade or other structural applications. Silt and sand tend to be more susceptible to frost action compared to clay and gravel. Environmental factors (e.g., weather and temperature) also significantly affect frost action, and thus climatic factors needed to be considered when evaluating DM as potential subgrade materials. For example, the climatic zone in the Great Lakes region is characterized as wet-freeze, based on the long-term pavement performance program. This means that a cold climate and supply of water are common during the winter, and thus frost heave tends to occur.

### 3.5 Backfill in Retaining Walls

Mechanically Stabilized Earth (MSE) is the term used to describe the practice of reinforcing a mass of soil with either metallic or geosynthetic soil reinforcement, which allows the mass of soil to function as a gravity retaining wall structure (WisDOT). An MSE wall system consists of the original ground, concrete leveling pad, wall facing panels, coping, soil reinforcement, select backfill and any loads and surcharge.

Grain size distribution, permeability, and soil strength are critical properties when evaluating if a material can be used as backfill in an MSE wall application. These characteristics are closely correlated. Gradation is used to differentiate two basic soil types: fine-grained soil and coarse-grained soil, which in turn affects permeability and shear strength. Compared to fine-grained soil, coarse-grained soil has a higher hydraulic conductivity and strength (friction angle), both of which are critical properties to consider for backfill applications (Table 3.2).

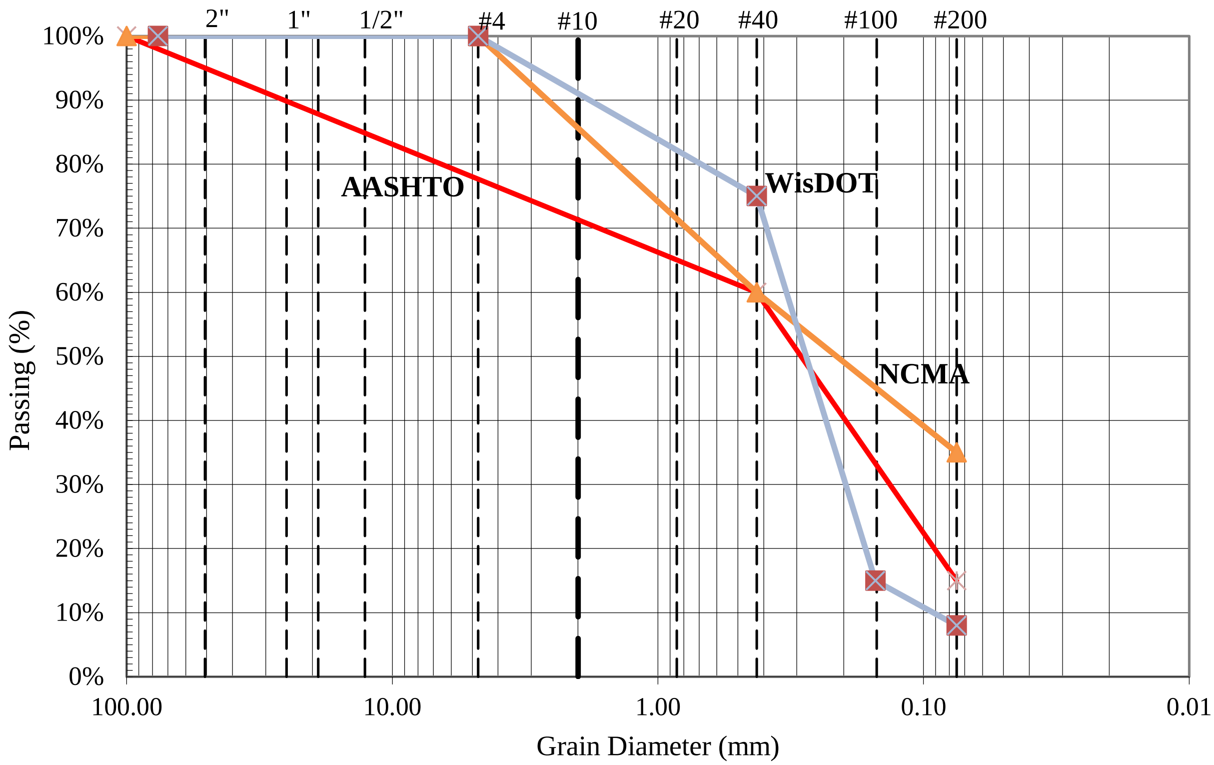
Table 3.2 Soil Properties in Backfill of MSE Wall

| Wall backfill Classification | Description | USCS Classification | Friction Angle ($\phi$) Range | Hydraulic Conductivity Range (cm/s) |
|---|---|---|---|---|
| Good | Sand, Gravel, Stone | GW,GP,GM,GC,SW,SP | $32^\circ$ - $36^\circ$ | $10^{2}$ - $10^{-2}$ |
| Moderate | Silty Sands, Clayey Sands | SM,SC | $28^\circ$ - $32^\circ$ | $10^{-2}$ - $10^{-6}$ |
| Difficult | Silts, Low Plastic Clays | ML,CL,OL | $25^\circ$ - $30^\circ$ | $10^{-6}$ - $10^{-10}$ |
| Bad | High Plastic Silts and Clay, Organics | CH,MH,OH,Pt | $0^\circ$ - $25^\circ$ | $10^{-6}$ - $10^{-10}$ |

Figure 3.1 indicates the upper limit of gradation for backfill soils based on synthesis of specifications from WisDOT, AASHTO, and the National Concrete Masonry Association (NCMA). Due to potential drainage and strength problems with fine-grained soils, 48 states limit the material passing the #200 (75 μm) sieve to no more than 15%, which conforms to the AASHTO requirement (Christopher and Stulgis, 2005). In general, fine-grained soil (at least 50% finer than #200 sieve), especially that with high plasticity, has limited use for backfill applications.

Permeability is another important soil property in backfill considerations. Drainage is crucial for MSE wall performance, since poor backfill drainage can lead to elevated pore pressure, a decrease in effective stress, low soil strength, and correspondingly large lateral forces on the wall. Permeability decreases with increasing percentage of fines. During wetting of reinforced soil, pore water pressure generation and loss of strength are inevitable if drainage is poor.

Figure 3.1 Upper Limit of Gradation for Backfill




MSE wall design generally consists of three analyses: working stress, equilibrium, and deformation. All three analyses need to consider the soil strength. Internal friction angle and shear strength are extremely useful properties when evaluating the suitability of soil as backfill and measuring the safety factor of slopes. According to AASHTO, a 34$^{o}$ friction angle is a minimum value permitted, since that angle is approximately the shear strength that will mobilize in the structure for most granular soils meeting the gradation requirements (Anderson, et al, 2012).

There are many other properties affecting backfill soil performance, such as modulus (Christopher, 1993), compaction (compressibility), shrink and swell potential and frost susceptibility. All of these factors are important considerations in the performance of backfill soil when using relative high percentage fine grained soil that still fulfill the AASHTO or DOTs' specifications.

High quality granular is considered primary choice as backfill material in MSE wall applications. To evaluate the beneficial use of DM in such applications, it is necessary to consider the implications of using fine-grained soils (a major component of most DM) as an alternative. In 1998, for example, the Louisiana Transportation Research Center (LTRC) constructed a full-scale reinforced test wall for studying the feasibility of using available low quality silty-clay as an economical and practical solution for the construction of MSE walls where high quality backfill is not readily available. By monitoring the lateral and vertical deformations over four years, it was found that there was a relatively high amount of deformation as compared to conventionally designed walls. LTRC recommended a detailed drainage system behind the if using fined grained soils in such applications.

# Chapter 4: Geotechnical Properties and Test Methods

## 4.1 Scope

This chapter summarizes specific values geotechnical engineering properties of DM as potential source materials for specific transportation sector uses. Physical properties including particle size distribution, Atterberg limits, density, water content, and organic content all influence the applicability and potential use of DM in construction. Hydraulic conductivity, compaction characteristics, consolidation characteristics, stiffness and shear strength are also relevant engineering properties. Testing standards (Table 4.1) are also discussed in this chapter.

Table 4.1 ASTM Designation versus AASHTO Designation

| | Test Category | ASTM | AASHTO | Description |
|---|---|---|---|---|
| Sampling | | D75 | T2 | Sampling Aggregates |
| Physical Properties | Particle Characteristics | D2488/D3398 | | Visual classification/Aggregate Particle Shape and Texture |
| | Sieve Analysis | D422 | T88 | Particle-Size Analysis (soil) |
| | | C136 | T27 | Particle-Size Analysis (aggregates) |
| | | D5444 | T30 | Gradation of Extracted Aggregate |
| | | D2217 | T146 | Wet Preparation of Soil Samples for Particle-Size Analysis |
| | | C117 | T11 | Percent Passing The 200 Sieve (aggregates) |
| | | D1140 | | Percent Passing The 200 Sieve (soil) |
| | Atterberg Limits | D4318 | T89 (LL)<br>T90 (PI) | Liquid Limit, Plastic Limit, and Plasticity Index of Soils |
| | Organic Matter | D2974 | T267 | Organic Content (loss on ignition) |
| | Specific Gravity | D854 | T100 | Specific Gravity of Soil |
| | Density | D1556 | T191 | In-Place Density and Unit Weight (Sand-Cone Method) |
| | | D2937 | T204 | In-Place Density (Drive Cylinder Method) |
| | | D6938 | T310 | In-Place Density and Water Content (Nuclear Method) |
| | Moisture Content | D2216 | T265 | Moisture Content (soil) |
| | | C566 | T255 | Moisture Content (aggregates) |
| Engineering Properties | Compaction | D698 | T99 | Standard Proctor Test |
| | | D1557 | T180 | Modified Proctor Test |
| | | D1883 | T193 | California Bearing Ratio |
| | | D558 | T134 | Moisture-Density Relations of Soil-Cement Mixture |
| | Durability | D559 | T135 | Wetting and Drying Compacted Soil-Cement Mixtures |
| | | D560 | T136 | Freezing and Thawing Compacted Soil-Cement Mixtures |
| | Consolidation | D2435 | T216 | One-Dimensional Consolidation |
| | Stiffness | D2844 | T190 | Resistance R-Value and Expansion Pressure of Compacted Soils |
| | | | T307 | Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials |
| | Shear Strength | D3080 | T236 | Direct Shear (under consolidated drained condition) |
| | | D2166 | T208 | Unconfined Compressive Strength of Cohesive Soil |
| | | D2850 | T296 | Unconsolidated Undrained Triaxial Compression (Q-Test) |
| | | D7181 | | Consolidated Drained Triaxial Compression (S-Test) |
| | | D4767 | T297 | Consolidated Undrained Triaxial Compression (R-Test) |
| | Wear | C131 | T96 | Resistance to Degradation of Small Size Coarse Aggregate |
| | Soundness | C88 | T104 | Sodium Sulfate Soundness (aggregates) |
| | | | T103 | Freeze/Thaw Soundness (aggregates) |
| | Hydraulic Properties | D2434 | T215 | Permeability of Granular Soils (constant head) |
| | | D5084 | | Hydraulic Conductivity (flexible wall) |
| | | D5856 | | Hydraulic Conductivity (rigid wall) |

## 4.2 Physical Properties

### 4.2.1 Particle Characteristics

Particle Characteristics including grain size distribution and particle shape influence the geotechnical properties of DM and are a primary indicator for assessing the quality and expected performance of construction materials. Grain size distribution (GSD) influences the density and water content. Grain size distribution and particle shape also influence the stability, shear strength, permeability, compressibility, and compactability. ASTM D422 is the standard test method for particle-size analysis of soils (with corresponding AASHTO standard in Table 4.1). Grain shape is also important. Rounded particles tend to provide better workability and easier compaction. Angular particles, on the other hand, tend to interlock and can result in a stable, dense mass capable of significant bearing capacity. The strain required to reach failure is approximately twice as large for angular-shaped particles as that required to reach failure for spherical particles.

### 4.2.2 Atterberg Limits

The objective of Atterberg limits testing is to obtain basic index information about the fine-grained fraction of soils or to indirectly estimate strength and settlement characteristics. Atterberg limits most commonly measured in practice include the liquid limit (LL) and plastic limit (PL), and can be used to assess the amount of dewatering needed before DM can be handled and processed. The LL, PL, and corresponding plasticity index (PI = LL – PL) are commonly used when investigating DM in harbors and confined disposal facilities (CDFs) or for evaluating suitability of any raw construction material in roadway construction. Some engineering properties, such as shear strength, shrink-swell compressibility and hydraulic conductivity (permeability), can be correlated with Atterberg Limits. The plasticity index (PI), liquidity index (LI), and activity index (AI) are derived from the PL and LL. PI is predominantly related to clay content. Large PI materials generally have a higher percentage of clay than materials having low PI. The effects of water content on the strength of saturated remolded soils can be quantified using the liquidity index. Activity index can potentially be used to identify the type of clay minerals present in raw DM.

### 4.2.3 Water Content

Water content is one of the most important factors affecting geotechnical properties (compaction, compressibility and shear strength) of DM. High water content in sediments could preclude use of DM in road construction as fill, subgrade or base material. Dewatering of raw DM with high water content may be necessary in roadway construction projects. The relation between density and water content determined via compaction testing is also important in applications such as pavement bases or fills.

### 4.2.4 Organic Content

Organic matter from plants, microbes, and carbonaceous materials may be prevalent in DM. In some cases, high levels of organic matter has some benefits, such as in applications requiring improved water infiltration (permeability). More generally, however, high organic content material is not desirable for use in roadway construction. Soils with high levels of organics generally have lower shear strength, higher compressibility, and higher shrinkage potential than those composed mainly of inorganic minerals. High shear strength, low compressibility, and low shrinkage potential are all important characteristics when evaluating material suitability in construction. According to NYDOT specifications, raw materials for embankments should be inorganic. Soils containing greater than 3% by dry weight calcium, magnesium carbonate, or organic material are generally not allowed within the specified thickness of the subgrade.

## 4.3 Engineering Properties

### 4.3.1 Hydraulic Properties

Hydraulic properties include permeability and hydraulic conductivity. Permeability is dependent on the pore size, pore geometry, and pore size distribution, and is independent of the fluid properties, whereas hydraulic conductivity is dependent on fluid properties. Permeability is one of the factors that influences shear strength through its influence on pore pressure and corresponding effective stress. Permeability also is an important indicator of the degree of frost susceptibility. Silts or silty sands with relatively low permeability can be susceptible to severe frost action. ASTM D2434, D5084, and D5856 are the major test methods for determining of the coefficient of permeability in granular soils that are primary materials for building embankments and bases.

### 4.3.2 Compaction

Compaction of porous material increases the amount of solids per unit volume. Compaction generally improves engineering properties so that the required shear strength, structure, and void ratio are obtained, while decreasing the shrinkage, permeability, and compressibility. Compaction is often required when building sub-grades or bases for airport pavements, roads, embankments, earth fill dams, or similar structures.

Laboratory Proctor tests and California Bearing Ratio (CBR) tests are two commonly used compaction tests in transportation-related construction. Procter tests include the standard, modified, and the 15-blow compaction tests. The standard compaction test is generally used in routine foundation and embankment design to simulate field compaction; the modified compaction test is used when a higher level of compaction is desired; and the 15-blow compaction test is used when lower levels of compaction are required. The standard Proctor test (ASTM D698) is for coarse-grained soils and low-plasticity fine-grained soils. For most DM, with medium to high plasticity and fine grained soils, the modified Proctor test (ASTM D1557) may be more suitable.

The CBR test (ASTM D1883) is used to determine resistance to penetration of a material (sub grades or bases). Its primary use has been in the design of flexible pavements located in areas where frost action is not a controlling factor. Since moisture affects the results, tests must be conducted using a moisture content that approximates the moisture content anticipated at the site where the pavement is to be constructed. CBR values usually range from 3 to 80 depending on the type of material tested.

### 4.3.3 Consolidation

Consolidation tests are required to estimate long-term settlement and plastic deformation likely to occur when soil is subjected to increasing pressures or loads and to determine the compressibility of the material. It is a rate process based on the time required for pore fluid to flow out of soil pores (void-ratio reduction).The rate of consolidation is dependent on (a) the degree of saturation, (b) the coefficient of soil permeability, (c) the nature of pore fluid (air or water), and (d) the distance the pore fluid has to travel for equilibrium to occur. The amount of consolidation or settlement likely to occur must be determined before DM is used as a base or subgrade. ASTM D2435 is standard test method for one-dimensional consolidation properties of soils.

#### 4.3.4 Stiffness

Relevant stiffness tests mainly include the Resistance Value (R-value) test and Resilient Modulus ($M_R$) test. The Resistance Value (R-value) test procedure quantifies a material's resistance to deformation as a function of the ratio of transmitted lateral pressure to applied vertical pressure. According to WisDOT specifications, the R-value test is necessary for evaluating soils as subgrade materials. ASTM D2844 is the standard method for testing R-value and expansion pressure of compacted soils.

Resilient Modulus is a dynamic soil property determined from the ratio of axial cyclic stress to the recoverable strain. A material's resilient modulus is an estimate of its modulus of elasticity (E). While the modulus of elasticity is stress divided by strain for a slowly applied load, resilient modulus is stress divided by strain for rapidly applied and repeated loads such as those experienced by pavements. The resilient modulus test provides a means of characterizing base, sub-base and subgrade materials for the design of pavement systems. It indicates basic material properties which can be used in mechanistic analysis of multilayered systems for predicting roughness, cracking, rutting, and faulting. AASHTO T307 is the standard method for testing Resilient Modulus of subgrade soils and untreated base/subbase materials. AASHTO T292 is followed to prepare and test untreated subgrade soils and base/subbase materials for determination of resilient modulus. AASHTO also allows using CBR and R-value to estimate $M_R$ if the equipment for performing the resilient modulus test is not available. For fine grained soils, the following equations can be used to evaluate the $M_R$:

$$M_R \text{ (psi)} = 1500 * CBR$$

$$M_R = 1000 + 555 * R\text{-value}$$

#### 4.3.5 Shear Strength

Shear strength is an important engineering property when evaluating DM as pavement structural materials or backfills in retaining wall systems. When using materials as embankment or backfills, shear strength parameters (undrained shear strength, cohesion, and friction angle) are typically used determine the safety factor of slope. Shear strength parameters may be determined using a number of laboratory and field tests.

# Chapter 5: Properties of Dredged Materials from Select Great Lakes Locations

## 5.1 Scope

This chapter summarizes geotechnical properties of representative DM samples from select harbors in the Great Lakes region: West Arm-Burns harbor, Waukegan harbor, Indiana harbor, Calumet harbor, and Milwaukee harbor. Results from West Arm-Burns, Waukegan, Indiana, and Calumet were synthesized from reports available in the literature. Results for the Milwaukee harbor material were obtained in the UW-Madison laboratory using representative samples obtained on site.

## 5.2 West Arm-Burns Harbor

### 5.2.1 Introduction

West Arm-Burns Harbor is located in Porter County, Portage, Indiana (Figure 5.1). Results described here were synthesized from the Final Report for The Harbor Boring Project West Arm-Burns Harbor, Portage, Indiana (August 2003). Geotechnical characteristics were reviewed for material sampled from the east seawall of the harbor, including samples from two soil borings spaced approximately 1500 feet apart (BH-01-03 and BH-02-03). Analysis included physical index properties (particle size distribution, Atterberg limits, water content) and mechanical properties (unconfined compressive strength). Table 5.1 indicates the soil classification of raw DM samples from both boring locations. According to the borehole log, saturated silty fine sand (SM) and silty clay (CL) were encountered at boring location BH-01-03. At boring location BH-02-03, clay with various density, ranging from soft to very stiff, was found over a range of depths. Table 5.2 is summary of corresponding geotechnical properties.

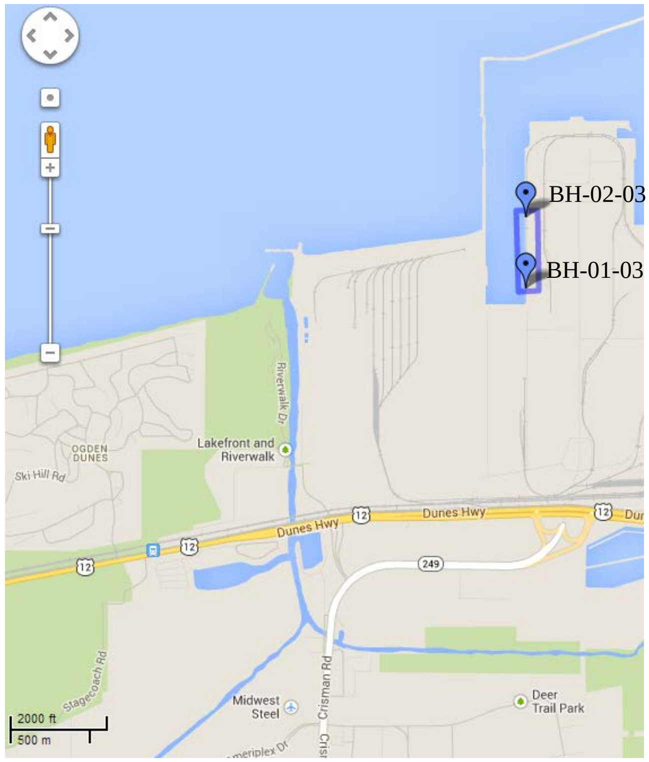
### 5.2.2 Physical Properties

A total of four particle size distribution tests (ASTM D2217) and five Atterberg limits tests (ASTM D4318) were reported in the 2003 final report. As Figure 5.2 indicates, the particle size distribution and corresponding Atterberg limits of samples from the boring BH-01-03 (samples SS-1-1, SS-1-5, and SS-1-10) classify as silty sand (SM). Samples from boring BH-02-03 classify predominantly as low plasticity clay (CL). Liquid limit and plasticity index does not vary significantly (Figure 5.3). According to Figure 5.4, water contents from different depths at the two locations tend to remain relatively constant and have an average value of 20.9 %.

### 5.2.3 Engineering Properties

Unconfined compressive strengths of representative materials are 5200 psf and 7400 psf at strain levels of 14.9% and 16.2%, respectively. Corresponding undrained shear strength, calculated as one half of the unconfined compressive strength, ranges from 2600 psf to 3700 psf.

Figure 5.1 Project Site of West Arm-Burns Harbor (2003)




: The location of DM samples collected

Table 5.1 Classification of DM samples from West Arm-Burns Harbor

| Soil Classification Type | Group | Number of Samples | Percent of Samples (%) |
|---|---|---|---|
| Total | - | 39 | 100 |
| Gravel | G | 0 | 0 |
| Silty Sand | SM | 12 | 31 |
| Low Plastic Silt | ML | 1 | 2 |
| Low Plastic Clay | CL | 26 | 67 |

Table 5.2 Geotechnical Results of DM Samples in West Arm-Burns Harbor

| Geotechnical Properties | Atterberg Limits | | Natural Moisture Content (%) | Unconfined Compressive Strength | |
|---|---|---|---|---|---|
| | LL | PI | | Strength (psf) | @ Strain (%) |
| Average (%) | 29 | 14 | 21 | 6300 | 15.5 |
| Maximum (%) | 33 | 18 | 39 | 7400 | 16.1 |
| Minimum (%) | 26 | 11 | 15 | 5200 | 14.9 |
| Number of Samples | 5 | 5 | 27 | 2 | |

Figure 5.2 Grain Size Distribution of DM Samples in West Arm-Burns Harbor

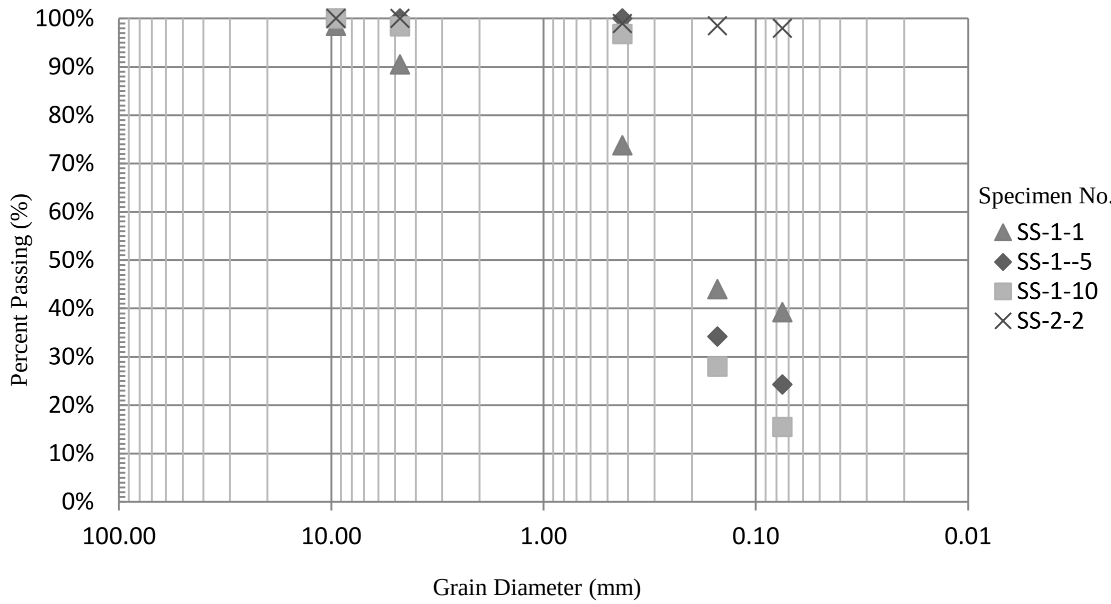



Figure 5.3 Atterberg Limits of DM samples in West Arm-Burns Harbor

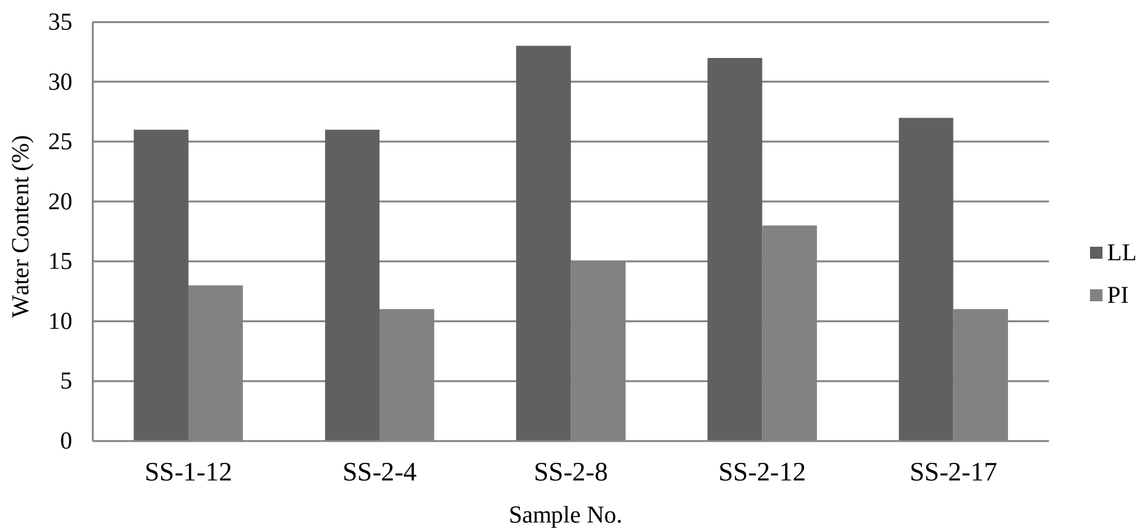
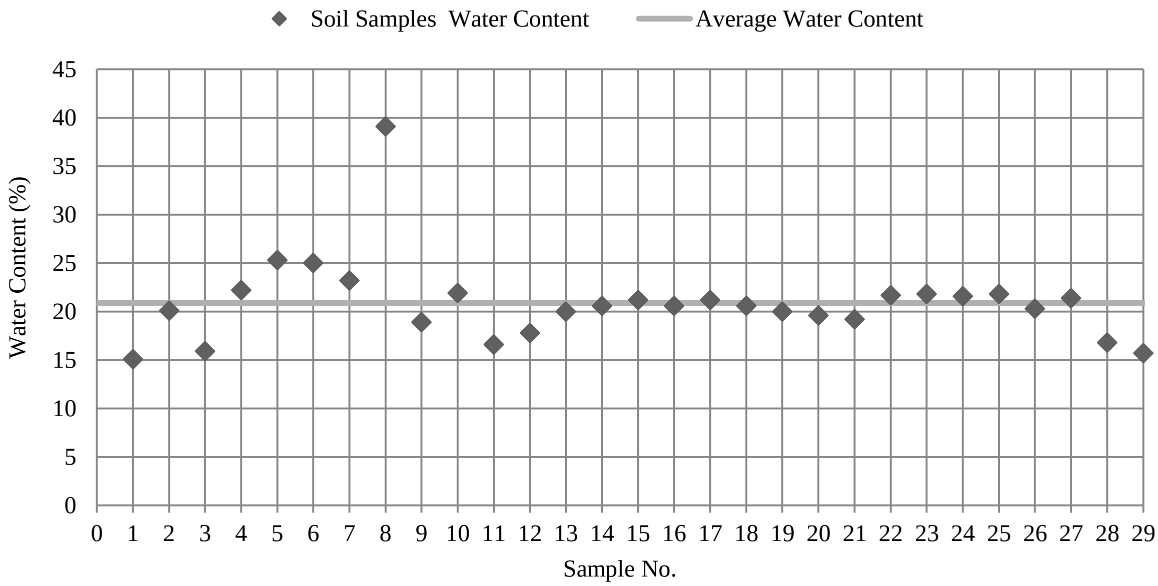


Figure 5.4 Water Content of DM Samples in West Arm-Burns Harbor




## 5.3 Waukegan Harbor

### 5.3.1 Introduction

Sediments in Waukegan Harbor (Figure 5.5) located in Illinois have been researched for several decades. Representative geotechnical properties for DM in the harbor, including grain size, plasticity, density, compaction characteristics, and shear strength properties were obtained by review of a report associated with those efforts. (Summary of Sediment Sampling Events and Analytical Results for Waukegan Inner Harbor and Entrance Channel, April 1998 and Data Evaluation Summary Report Waukegan Harbor Area of Concern, Waukegan, IL, April 2005).

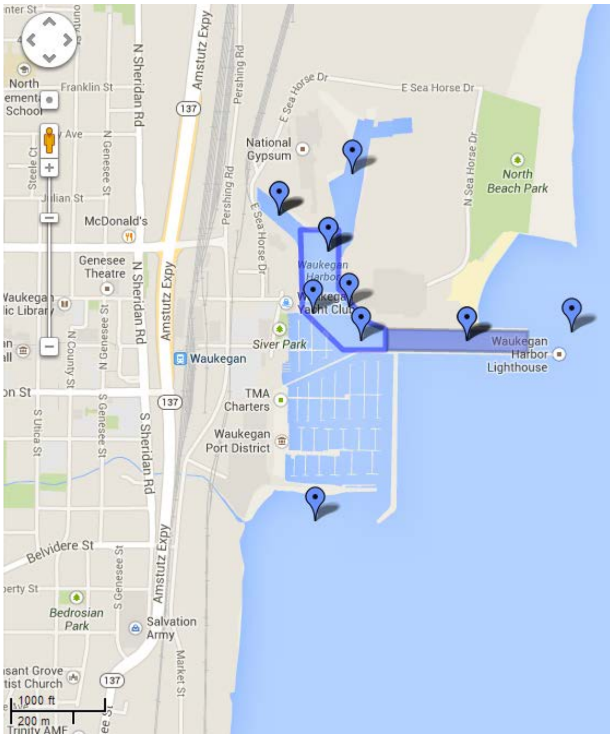
### 5.3.2 Physical Properties

As summarized in Table 5.3 and Figure 5.6, major soil types are silt and sand (67% and 22% respectively). Five of the nine total samples considered can be classified as ML (low plasticity silt) (Figure 5.7). Water content tends to vary significantly and can be as high as 80% to 120% (Figure 5.8). Organic content measured for of 44 samples in the harbor indicates that ten samples have organic content higher than 5%, with an average value for all samples of 3%.

### 5.3.3 Engineering Properties

Results from standard Proctor compaction tests to determine optimum water content and maximum dry density are summarized in Table 5.4. Results from direct shear tests to determine cohesion intercept and friction angle are also synthesized in the table.

Figure 5.5 Project Site of Waukegan Harbor




: The location of DM samples collected

Table 5.3 Classification of DM samples from Waukegan Harbor

| Soil Classification | Number of Samples | Percent of Samples (%) |
|---|---|---|
| Gravel | 0 | 0 |
| Sand | 2 | 22 |
| Silt | 6 | 67 |
| Clay | 1 | 11 |
| Total | 9 | 100 |

Table 5.4 Geotechnical Results of DM Samples in Waukegan Harbor

| Geotechnical Properties | Atterberg Limits | | Moisture Content (%) | Specific Gravity | Organic Content (%) | Standard Compaction | | Direct Shear | |
|---|---|---|---|---|---|---|---|---|---|
| | LL (%) | PI (%) | | | | Opt. Water Content (%) | Max. Dry Density (pcf) | Cohesion (psf) | Friction Angle (deg.) |
| Average | 33.6 | 9.3 | 68 | 2.5 | 3.0 | 15 | 103.2 | 143 | 34.6 |
| Maximum | 49.8 | 17.6 | 121 | 2.7 | 7.9 | 15.6 | 106.4 | 200 | 35 |
| Minimum | 24.5 | 3.8 | 28.7 | 2.3 | 0.4 | 14.1 | 99.6 | 100 | 34.1 |
| Number of Samples | 7 | | 9 | | 44 | 3 | | | |

Figure 5.6 Grain Size Distribution of DM Samples in Waukegan Harbor

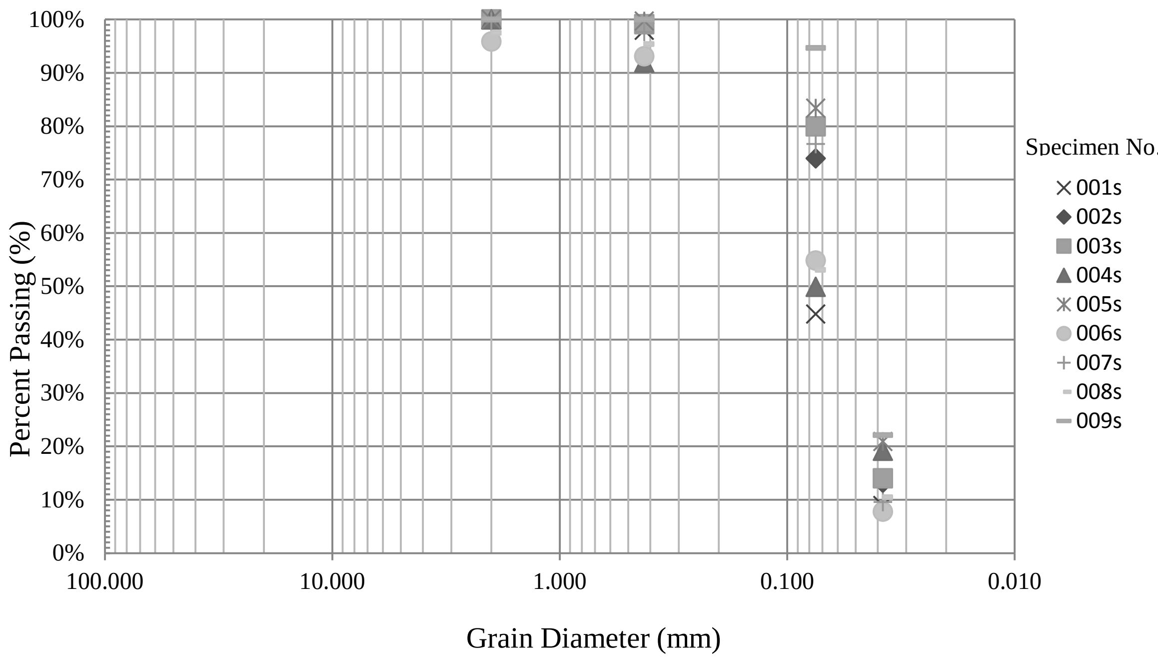



Figure 5.7 Atterberg Limits of DM Samples in Waukegan Inner Harbor

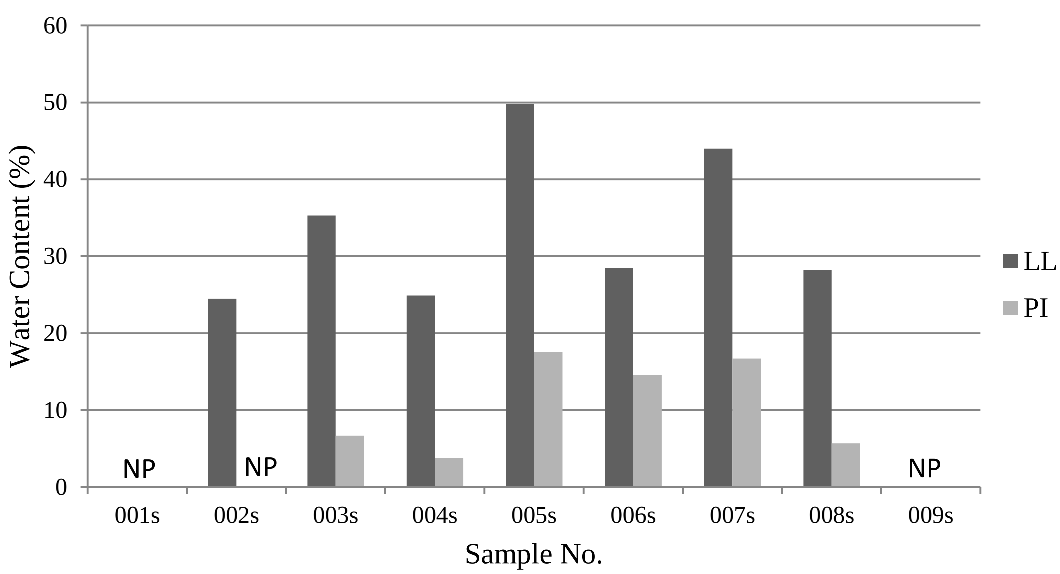
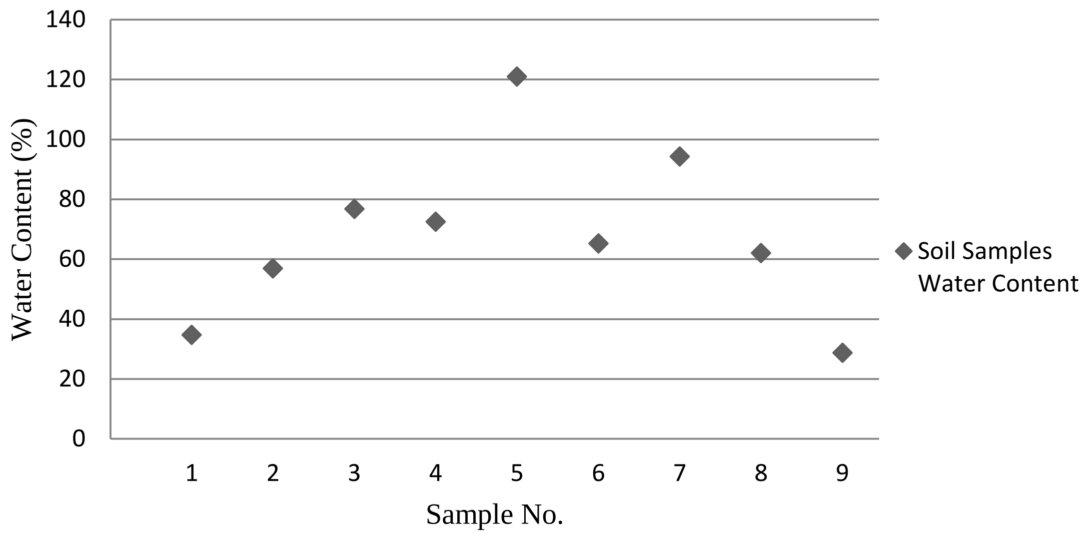


Figure 5.8 Water Content of DM Samples in Waukegan Harbor




## 5.4 Indiana Harbor

### 5.4.1 Introduction

The Indiana Harbor and Canal (Figure 5.9) is an artificial waterway located on the southwest shore of Lake Michigan, in East Chicago, Indiana. The Main Canal connects the Grand Calumet River to Lake Michigan from two branch canals through Indiana Harbor. Representative geotechnical properties for DM in the harbor, including grain size, plasticity, density, consolidation characteristics, hydraulic conductivity, and shear strength properties were obtained by review of reports from sampling performed in the Harbor and Main Canal, near the harbor. (Sediment Sampling and Analysis Report Indiana Harbor and Canal Harbor, Indiana September 2010 and Geotechnical Engineering Services For the Indiana Harbor Confined Disposal Facility Chicago CDF Borrow Source Material Testing Project, September 2009).

### 5.4.2 Physical Properties

As summarized on Figure 5.10 and Figure 5.11, representative samples classify as CL (low plasticity clay). Water content changes variably and specific gravity tends to remain constant (Table 5.6).

### 5.4.3 Engineering Properties

Hydraulic conductivity, triaxial shear strength and standard compaction test results are summarized in Table 5.6.

Figure 5.9 Project Site of Indiana Harbor (2010)


: The location of DM samples collected

Table 5.5 Classification of DM Samples from Indiana Harbor

| Soil Classification | Number of Samples | Percent of Samples (%) |
|---|---|---|
| Gravel | 0 | 0 |
| Sand | 8 | 38 |
| Silt | 0 | 0 |
| Clay | 9 | 43 |
| Organic fines | 4 | 19 |
| Total | 21 | 100 |

Table 5.6 Geotechnical Results of DM Samples in Indiana Harbor

| Geotechnical Properties | Atterberg Limits | | Moisture Content (%) | Specific Gravity | Compaction | | Hydraulic Conductivity (cm/sec) | Consolidated-Undrained (CU) | | | | Unconsolidated-Undrained (UU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LL (%) | PI (%) | | | Opt. Water Content (%) | Max. Dry Density (pcf) | | Total Cohesion (psf) | Total Friction Angle (deg.) | Effective Cohesion (psf) | Effective Angle (deg.) | Cohesion (psf) | Friction Angle (deg.) |
| Average | 42 | 19.3 | 32.5 | 2.70 | 18.8 | 103.0 | 2.06E-07 | 104.9 | 25.7 | 63.7 | 36.5 | 1036.7 | 14.8 |
| Maximum | 48 | 24 | 42.6 | 2.71 | 19.3 | 108.7 | 4.82E-07 | 147.4 | 29.4 | 111 | 36.5 | 1124 | 23.7 |
| Minimum | 36 | 17 | 17.9 | 2.69 | 18 | 99 | 6.14E-08 | 24.2 | 20.9 | 15.2 | 36.4 | 968 | 0 |
| Number of Samples | 3 | | | | | | | | | | | | |

Figure 5.10 Grain Size Distribution of DM Samples in Indiana Harbor

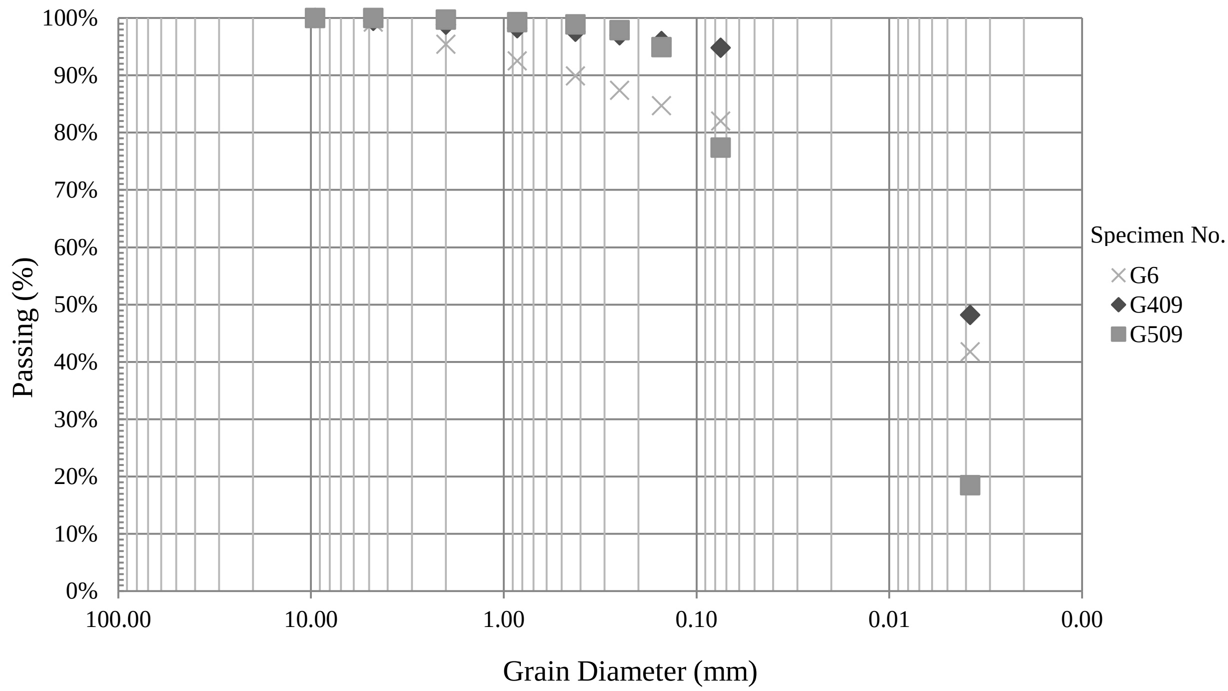
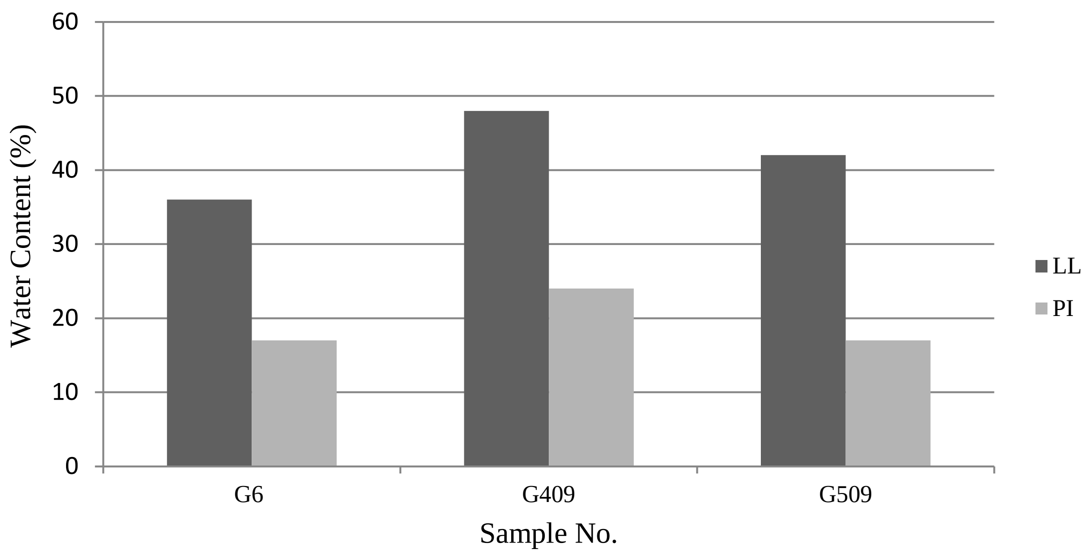



Figure 5.11 Atterberg Limits of DM Samples in Indiana Harbor



## 5.5 Calumet Harbor (Chicago Area CDF)

### 5.5.1 Introduction

The Chicago Area confined disposal facility (CDF) is located on the southern corner of the intersection of Lake Michigan and the Calumet River (Figure 5.12). Representative geotechnical properties, including grain size, plasticity, density, consolidation characteristics, and shear strength properties were obtained by review of reports from the US Army Corps of Engineers (USACE). (Collection and Analysis of Environmental Samples for Calumet Harbor and River Dredged Material Management Plan (DMMP), July 2006).

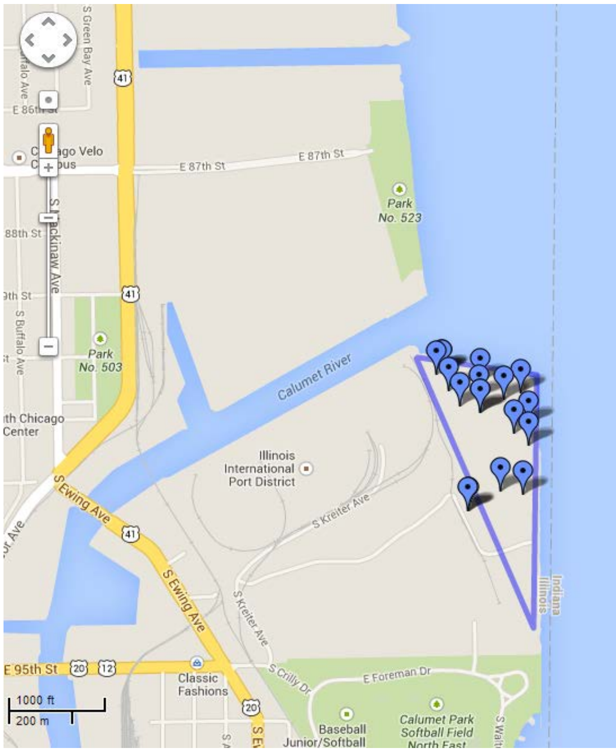
### 5.5.2 Physical Properties

Based on grain size distribution (Figure 5.13), representative materials at the site fall into the general category of fine-grained soils. Other physical properties, such void ratio, density, water content, and specific gravity are summarized on Table 5.7.

### 5.5.3 Engineering Properties

Results from two triaxial compressions tests (CU and UU) are summarized on Table 5.9. Figure 5.14 indicates the relationship between applied load in a 1D consolidation test and coefficient of consolidation.

Figure 5.12 Project Site of Calumet Harbor (2006)




: The location of DM samples collected

Table 5.7 Classification of DM Samples from Calumet Harbor

| Soil Classification | Number of Samples | Percent of Samples (%) |
|---|---|---|
| Gravel | 0 | 0 |
| Sand | 30 | 26 |
| Silt | 56 | 49 |
| Clay | 29 | 25 |
| Total | 115 | 100 |

Figure 5.13 Grain Size Distribution of DM Samples in Calumet Harbor (Chicago Area CDF)

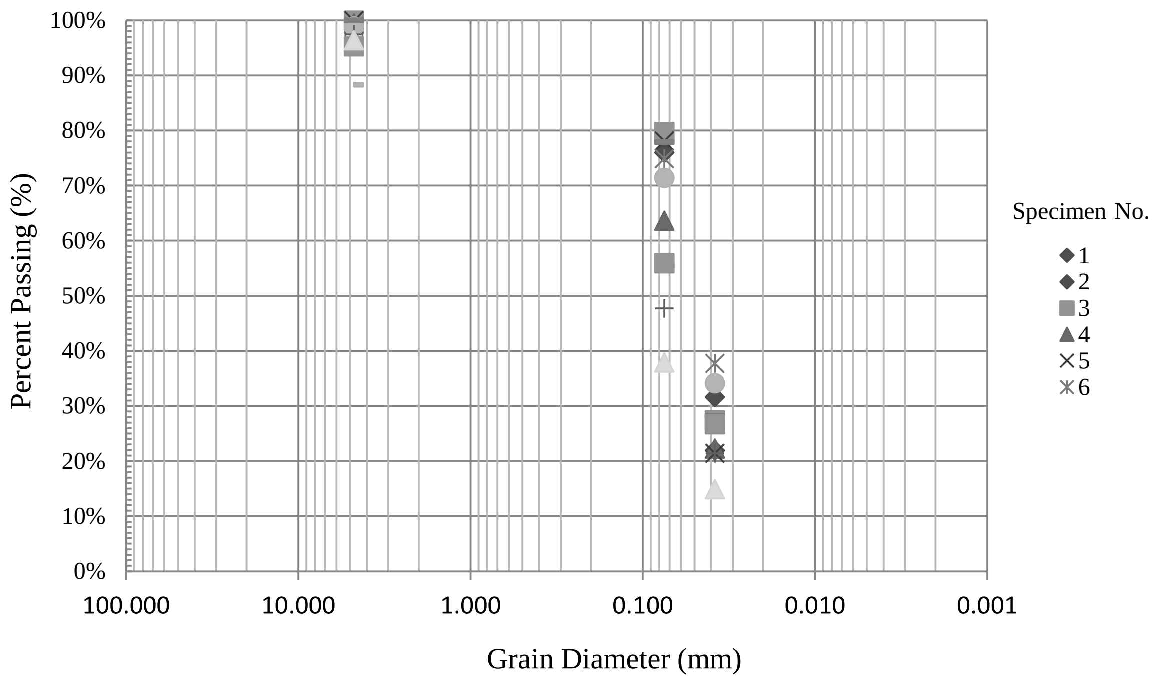


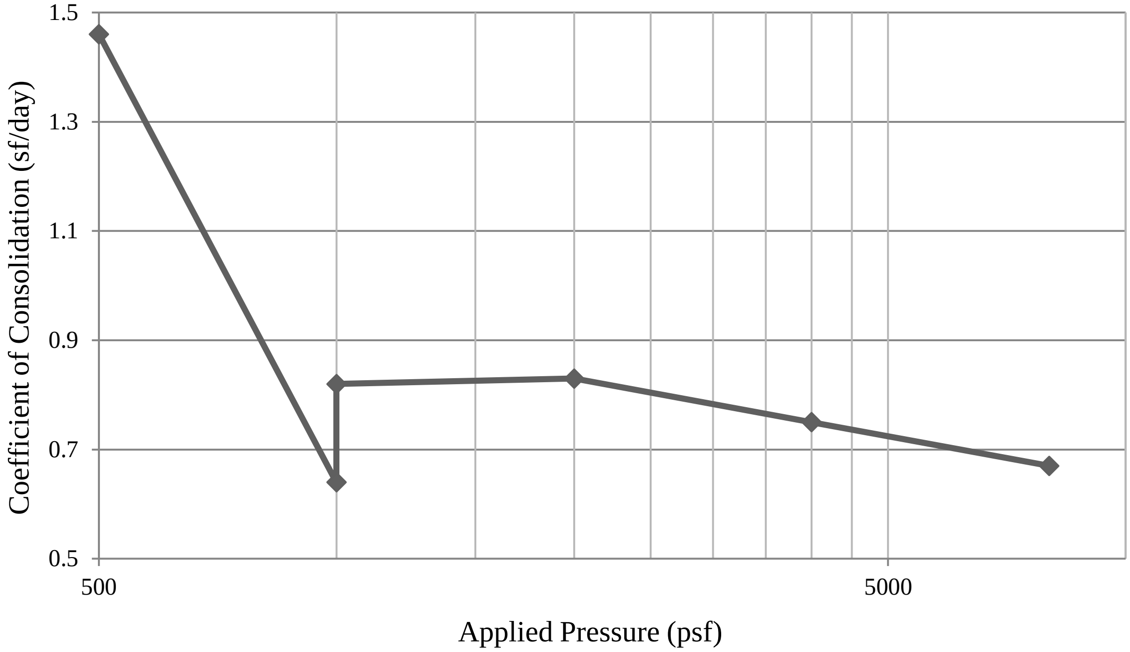
Table 5.8 Geotechnical Results of DM Samples in Calumet Harbor

| Geotechnical Properties | Atterberg Limits | | Moisture Content (%) | Specific Gravity | Dry Density (psf) | Total Porosity (%) | Consolidated-Undrained (CU) | | | | Unconsolidated-Undrained (UU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LL (%) | PI (%) | | | | | Total Cohesion (psf) | Total Friction Angle (deg.) | Effective Cohesion (psf) | Effective Angle (deg.) | Cohesion (psf) | Friction Angle (deg.) |
| Average | 43.8 | 16 | 32.5 | 2.70 | 18.8 | 103 | 380 | 21.1 | 140 | 30.8 | 100 | 3.4 |
| Maximum | 47 | 17 | 42.6 | 2.71 | 19.3 | 108.7 | 720 | 36.5 | 250 | 33.9 | 130 | 6.7 |
| Minimum | 40 | 15 | 17.9 | 2.69 | 18 | 99 | 40 | 5.6 | 30 | 27.6 | 70 | 0 |
| Number of Samples | 4 | | 12 | | | | 2 | | | | | |

Table 5.9 Triaxial Compression Results for Soil Samples from Chicago Area CDF

| Soil Samples | Consolidated-Undrained (CU) | | | | Unconsolidated-Undrained (UU) | |
|---|---|---|---|---|---|---|
| | Total Cohesion (psf) | Total Friction Angle (deg.) | Effective Cohesion (psf) | Effective Friction Angle (deg.) | Cohesion (psf) | Friction Angle (deg.) |
| G1 | 720 | 5.6 | 250 | 27.6 | 70 | 6.7 |
| G2 | 40 | 36.5 | 30 | 33.9 | 130 | 0 |

Figure 5.14 Consolidation Charateristics of DM Samples from Chicago CDF




## 5.6 Milwaukee Port

### 5.6.1 Introduction

The Port of Milwaukee is a port in the city of Milwaukee on Lake Michigan. It primarily serves Southeastern Wisconsin and Northern Illinois. DM samples obtained from the site were tested in soil laboratory in University of Wisconsin-Madison. Table 5.9 is summary of those results.

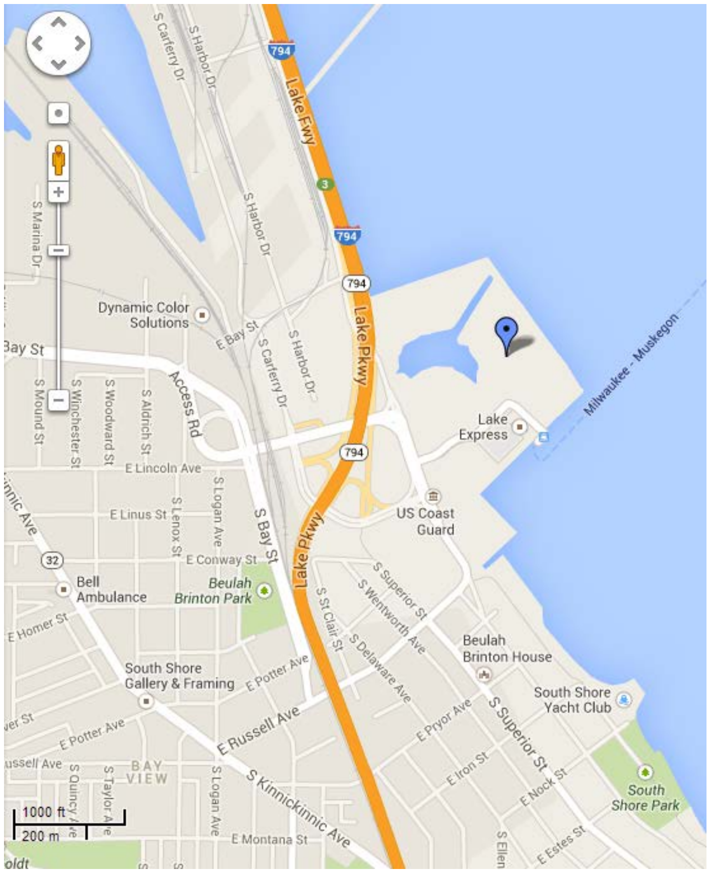
### 5.6.2 Physical Properties

Base on grain size distribution (Figure 5.16) and results from Atterberg limits (Table 5.10), materials at the site can be classified predominantly as low plastic clay (CL). Other physical properties, such as specific gravity, water content and organic content, are summarized on Table 5.10.

### 5.6.3 Engineering Properties

Results from conventional triaxial compression (UU), modified compaction test, and California Bearing Ratio (CBR) tests are summarized on Table 5.10.

Figure 5.15 Project Site of Milwaukee Port (2012)

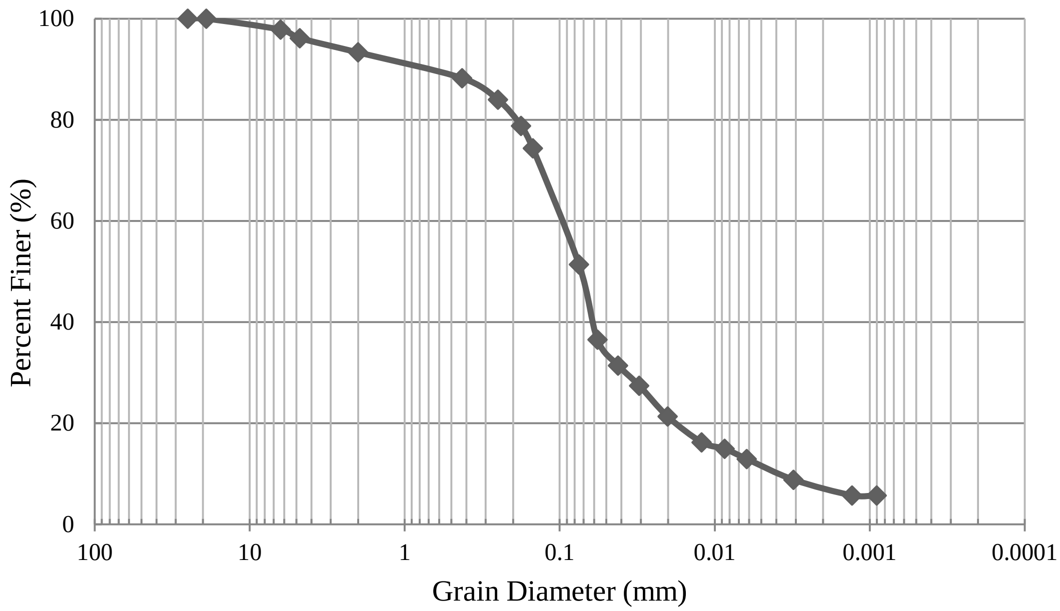



: The location of DM sample collected

Table 5.10 Geotechnical Results of DM Samples in Milwaukee Port

| Geotechnical properties | Specific Gravity | Water Content (%) | Hydraulic Conductivity (cm/s) | Organic Content (%) | Modified Compaction: Opt. Water Content (%) | Modified Compaction: Max. dry unit weight (pcf) | Cohesion (psf) | CBR |
|---|---|---|---|---|---|---|---|---|
| Raw DM | 2.72 | 22.4 | 1.70E-06 | 3.67 | 17 | 98.6 | 5012.5 | 12.8 |

Figure 5.16 Grain Size Distribution of DM Sample in Milwaukee Port



# Chapter 6: Implementation of a Beneficial Use Framework

## 6.1 Scope

As described in Chapter 1, the overall goal of this project includes several major objectives. Guidelines are being developed to link: 1) applications for use of DM in transportation-related projects, 2) required geotechnical properties, 3) available geotechnical test methods, 4) geotechnical specifications for specific uses, and 5) locations within the Great Lakes region where dredged materials meeting these specifications may be sourced. Previous chapters have addressed objectives 1, 2, 3, and 4. Chapter 5 summarized geotechnical properties from five select DM sources in the Great Lakes region. In this chapter, a framework for evaluating the potential use of DM in transportation projects is demonstrated for those select materials.

## 6.2 Framework Demonstration

The framework herein is derived primarily from Wisconsin DOT (WisDOT) specifications for earthwork construction. WisDOT standard specifications delineate geotechnical properties of soils in several transportation applications. Table 6.1 summarizes three earthwork applications (base, sub-base, and backfill), corresponding geotechnical properties of importance, and the corresponding American Association of State Highway and Transportation Officials (AASHTO) testing standards for determining these properties.

Table 6.2 is a more general summary of typical engineering characteristics for specific soil types and corresponding rating (applicability) in various transportation sector applications. Columns 1 and 2 show the USCS soil classification including major divisions and specific group symbols. Columns 3 and 4 give typical ranges of optimum water content and corresponding maximum dry unit weight based on standard proctor, AASHTO T99 (after Carter and Bentley, 1991). Columns 5 and 6 indicate typical ranges of cohesions and friction angles of different soil groups (www.geotechdata.info). Column 7 shows the typical ranges of permittivity of different soil groups (after Casagrande and Fadum, 1940). Column 8 evaluates drainage characteristics based on permittivity of soils (Sowers, et al. 1970). Column 9 shows the typical ranges of CBR value of soils (FM5-410, Military Soil Engineering). Column 10 evaluates the compressibility and expansion characteristics of soils (FM5-410, Military Soil Engineering). Column 11 evaluates the potential frost action of soils (FM5-410, Military Soil Engineering). Column 12 evaluates the compaction characteristics of soils (Sowers, et al. 1970). Column 13 evaluates soils value as embankment based on material suitability. Column 14 evaluates soils value as subgrade materials (FM5-410, Military Soil Engineering). Column 15 evaluates soils value as subbase courses (FM5-410, Military Soil Engineering). Column 16 evaluates soils value as base courses (FM5-410, Military Soil Engineering). Column 17 evaluates soils value as backfills in MSE wall.

Figure 6.1 is a flow chart developed in accordance with WisDOT specifications. The flow chart is intended to guide identification of suitable dredged materials for specific transportation applications. Vertical arrows with a “yes” in the flow chart indicate that the material fulfills the geotechnical requirements of the corresponding level. Horizontal arrows with a “no” indicate the material does not meet the specification.

### 6.3 Results and Recommendations

Based on the limited geotechnical information evaluated in available reports (Chapter 5), the representative materials in Indiana Harbor, West Arm-Burns Harbor and the Chicago area CDF may be considered clay with low plasticity (CL) (Table 6.3). Representative Waukegan Harbor material is considered low plasticity silt (ML). Average organic content in the Waukegan Harbor material is relatively low. However, the organic matter in DM from Chicago Area CDF is relatively high.

Considering the framework outlined in these figures and tables, un-amended or "raw" DM from Indiana Harbor, West Arm-Burns Harbor, the Chicago area CDF, and Waukegan Harbor could potentially be considered as embankment construction material. No material meets the gradation criteria for use as structural fill, backfill, or base material. Based this evaluation, the material potentially sourced from these locations has limited direct use for transportation-related construction in its raw or un-amended form. Review of general sediment types in harbors throughout the region, however, indicates that there may be large potential for beneficial use of DM because the sediment type from numerous harbors in the region is predominantly coarse-grained (Table 6.4). Fine-grained materials are also a potential source of material if amended or stabilized with other materials (e.g., fly ash). DM stabilization has been successfully used to enhance strength, reduce compressibility, and modify drainage characteristics. Future effort should focus on laboratory evaluation of stabilized fine-grained DM, detailed field characterization of the physical properties at DM sources throughout the region, and dissemination and outreach to promote the concept of beneficial use of dredged materials in transportation construction.

Table 6.1: Relevant Properties and Testing Standards for Three Transportation Earthwork Applications

| Transportation Sectors | | Geotechnical Properties | Testing Standards |
|---|---|---|---|
| Base | Open Graded Base & Dense Graded base | Gradation | AASHTO T27 |
| | | Wear | AASHTO T96 |
| | | Sodium sulfate soundness | AASHTO T104 |
| | | Freeze/thaw soundness | AASHTO T103 |
| | | Liquid limit | AASHTO T89 |
| | | Plasticity index | AASHTO T90 |
| | | Fracture | CMM 8-60 |
| Subbase | | Percent passing the 200 sieve | AASHTO T11 |
| | | Gradation | AASHTO T27 |
| | | Liquid limit | AASHTO T89 |
| | | Plasticity index | AASHTO T90 |
| Backfill | Structural Backfill | Percent passing the 200 sieve | AASHTO T2 |
| | | Gradation | AASHTO T11 |
| | Granular Backfill | percent passing the 200 sieve | AASHTO T11 |
| | | Gradation | AASHTO T27 |
| | | Liquid limit | AASHTO T89 |
| | | Plasticity index | AASHTO T90 |
| Embankment/Borrow | | No gradation requirements except highly frost, swelling, and compression susceptible or highly organic soils, such as CH, OH, and MH. | |

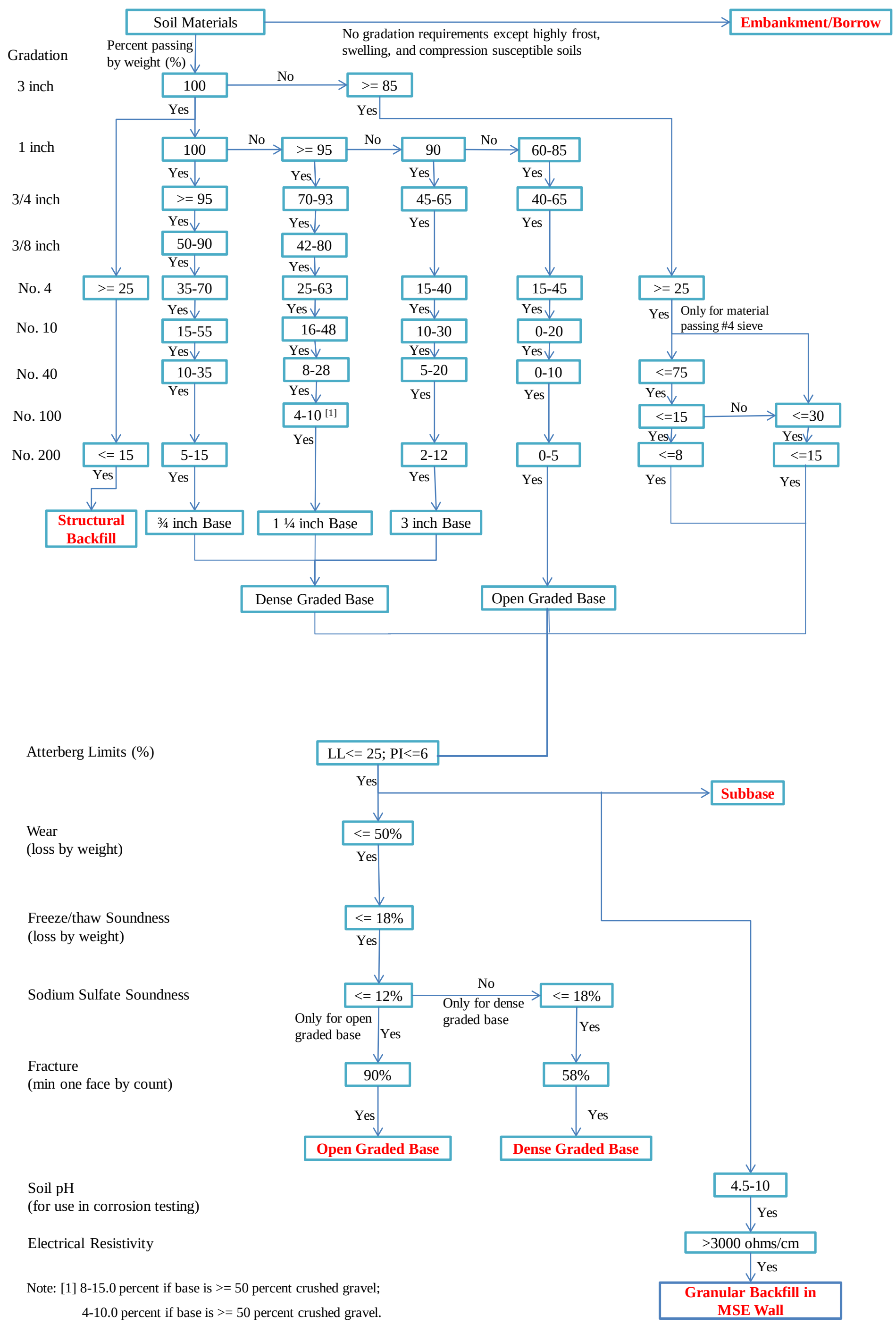



Figure 6.1 Framework for evaluation of soil suitability in the transportation sector

Table 6.2 Required Geotechnical Properties and Suitability for Several Applications

| Soil Classification | | Rating and Magnitude of Soil Engineering Properties | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USCS Divisions (1) | Symbols (2) | Optimum Water Content (%) (3) | | Max. Dry Unit weight (pcf) (4) | | Cohesion (psf) (5) | Friction Angle (deg.) (6) | Hydraulic Conductivity (cm/s) (7) | Drainage Characteristics (8) | CBR (9) | Compressibility and Expansion (10) | Potential Frost Action (11) | Compaction Characteristics (12) |
| Gravel and Gravelly Soil | GW | 8-11[a] | 11.4[b] | 125-135[a] | 124.2[b] | 0 | 33-41 | $>10^{-2}$ | good (pervious)[c] | 40-80 | almost none | none to very slight[d] | good |
| | GP | 11-14 | 11.2 | 115-125 | 121.7 | 0 | 35-41 | $>10^{-2}$ | good (pervious) | 30-60 | almost none | none to very slight | good |
| | GM | 8-12 | 15.8 | 120-135 | 113.3 | 0 | 32-38 | $10^{-3}$ - $10^{-6}$ | poor (semi pervious) | 20-60 | slight | slight to medium | good |
| | GC | 9-14 | 13.9 | 115-130 | 116.6 | 0 | 29-33 | $10^{-6}$ - $10^{-8}$ | poor (impervious) | 20-40 | slight | slight to medium | good |
| Sand and Sandy Soil | SW | 9-16 | 9.1 | 110-130 | 126.1 | 0 | 35-41 | $> 10^{-3}$ | good (pervious) | 20-40 | almost none | none to very slight | good |
| | SP | 12-21 | 10.8 | 100-120 | 115.6 | 0 | 31-39 | $> 10^{-4}$ | good (pervious) | 10-40 | almost none | none to very slight | good |
| | SM | 11-16 | 12.5 | 110-125 | 116.6 | 0 | 33-35 | $10^{-3}$ - $10^{-6}$ | poor (impervious) | 10-40 | slight | slight to high | good |
| | SC | 11-19 | 12.4 | 105-125 | 118.9 | 0 | 30-36 | $10^{-6}$ - $10^{-8}$ | poor (impervious) | 5-20 | slight to medium | slight to high | fair to good |
| Silt and Clay (LL<50) | ML | 12-24 | 19.7 | 95-120 | 103.3 | 0 | 29-37 | $10^{-3}$ - $10^{-6}$ | poor (impervious) | <= 15 | slight to medium | medium to very high | poor to good |
| | CL | 12-24 | 16.7 | 95-120 | 109.3 | 210-625 | 26-32 | $10^{-6}$ - $10^{-8}$ | no drainage (impervious) | <= 15 | medium | medium to high | fair to good |
| | OL | 21-33 | NA | 80-100 | NA | 105-315 | 22-32 | $10^{-4}$ - $10^{-6}$ | poor (impervious) | <= 5 | medium to high | medium to high | poor to fair |
| Silt and Clay (LL>50) | MH | 24-40 | 33.6 | 70-95 | 85.1 | 0-210 | 24-30 | $10^{-4}$ - $10^{-6}$ | poor (impervious) | <= 10 | high | medium to very high | poor to fair |
| | CH | 19-36 | 25 | 80-105 | 95.3 | 315-730 | 17-27 | $10^{-6}$ - $10^{-8}$ | no drainage (impervious) | <= 15 | very high | medium | poor to fair |
| | OH | 21-45 | NA | 65-100 | NA | 105-315 | 17-35 | $10^{-6}$ - $10^{-8}$ | no drainage (impervious) | <= 5 | high | medium | poor to fair |

Continued

| Soil Classification | | Soil Value as Transportation Sectors | | | | |
|---|---|---|---|---|---|---|
| USCS Divisions (1) | Symbols (2) | Embankment (13) | Subgrade (14) | Subbase (15) | Base (16) | Backfill in MSE Wall (17) |
| Gravel and Gravelly Soil | GW | excellent | excellent | excellent | good | good to excellent |
| | GP | fair to good | excellent to good | good | good to fair | excellent |
| | GM | fair to good | excellent to good | good to fair | good to unsuitable[2] | good to fair |
| | GC | fair to good | good | fair | poor to unsuitable | fair |
| Sand and Sandy Soil | SW | excellent | good | good to fair | poor | good |
| | SP | fair to good | good to fair | fair | poor to unsuitable | good |
| | SM | fair to good | good to fair | good to poor[1] | poor to unsuitable | fair |
| | SC | fair to good | good to fair | poor | unsuitable | poor |
| Silt and Clay (LL<50) | ML | poor | fair to poor | unsuitable | unsuitable | very poor to unsuitable |
| | CL | good | fair to poor | unsuitable | unsuitable | unsuitable |
| | OL | unsuitable | poor | unsuitable | unsuitable | unsuitable |
| Silt and Clay (LL>50) | MH | unsuitable | poor | unsuitable | unsuitable | unsuitable |
| | CH | fair | poor | unsuitable | unsuitable | unsuitable |
| | OH | unsuitable | poor to very poor | unsuitable | unsuitable | unsuitable |

Note:
1, If LL<25 and PI, SM' value as subbase ranged from fair to good. Otherwise, SM's value as subbase ranged from poor to fair.
2, If LL<25 and PI, GM's value as base ranged from fair to good. Otherwise, GM's value as subbase ranged from poor to unsuitable.
a, geotechdata.info
b, Average values of compacted soils from Western United States (USBR)
c, According USBR, k less than 1 ft/year as impervious (no drainage), k between 1 and 100 ft./year as semipervious (poor); k greater than 100 ft./year as pervious (good)
d, American Concrete Pavement Association (ACPA)

Table 6.3: Representative Material Properties in Select Harbors and CDFs

| Project Site | Soil Classification | Grain Size Distribution (%) | | | | Specific Gravity | Atterberg Limits (%) | | Organic Content (%) | Opt. Water Content (%) | Max. Dry Density (pcf) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gravel | Sand | Silt | Clay | | LL | PI | | | |
| West Arm-Burns Harbor | CL | 0 | 31 | 2 | 67 | NA | 28.8 | 13.6 | NA | NA | NA |
| Waukegan Harbor | ML | 0 | 22 | 67 | 11 | 2.5 | 33.6 | 9.3 | 3 | 14.6 | 64.7 |
| Indiana Harbor | CL | 0 | 38 | 0 | 62 | 2.7 | 42 | 19.3 | NA | 18.8 | 103 |
| Chicago Area CDF | CL | 0 | 26 | 49 | 25 | 2.7 | 43.8 | 27.5 | 10.5 | NA | NA |
| Milwaukee Port | CL | 4 | 44 | 41 | 10 | 2.7 | 32.5 | 12.2 | 3.7 | 17 | 96.8 |

Table 6.4. Representative Material Properties in the Great Lakes Region

| Harbor Project Site | Location | Sediment Type |
|---|---|---|
| Grand Marais | MN | Sand |
| Two Harbors | MN | Sand |
| La Pointe | MI | Sand |
| Black River | MI | Sand |
| Grand Traverse Bay | MI | Sand |
| Big Bay | MI | Sand |
| Whitefish Point Harbor | MI | Sand |
| St Marys River | MI | Mixed |
| Cedar River | MI | Sand |
| Ontonagon | MI | Sand |
| Lac La Belle | MI | Sand |
| Little Lake | MI | Sand |
| New Buffalo | MI | Sand |
| Saugatuck (Outer) | MI | Sand |
| St James | MI | Sand |
| Frankfort | MI | Mixed |
| Grays Reef | MI | Rocks |
| Leland | MI | Sand |
| Arcadia | MI | Sand |
| Greilickville | MI | Sand |
| Portage Lake | MI | Sand |
| Ludington (Outer) | MI | Sand |
| Manistee (Outer) | MI | Sand |
| Pentwater | MI | Sand |
| South Haven | MI | Sand |
| White Lake | MI | Sand |
| St Joseph (Outer) | MI | Sand |
| Muskegon (Outer) | MI | Sand |
| Eagle Harbor | MI | Sand |
| Grand Haven (Outer) | MI | Sand |
| Holland (Outer) | MI | Sand |
| Charlevoix | MI | Sand |
| Petoskey | MI | Sand |
| Inland Route | MI | Mixed |
| Mackinac City | MI | Sand |
| Lake St. Clair | MI | Sand |

Table 6.4 (Continued)

| Harbor Project Site | Location | Sediment Type |
|---|---|---|
| St Clair River | MI | Sand |
| Pine River | MI | Sand |
| Black River - St Clair Co | MI | Mixed |
| Lexington | MI | Fine |
| Port Sanilac | MI | Sand |
| Caseville | MI | Mixed |
| Bay Port | MI | Mixed |
| Sebewaing River | MI | Mixed |
| Point Lookout | MI | Mixed |
| Tawas Bay | MI | Sand |
| Au Sable | MI | Sand |
| Harrisville | MI | Sand |
| Alpena | MI | Mixed |
| Hammond Bay | MI | Fine |
| Detour | MI | Sand |
| Les Cheneaux Islands | MI | Sand |
| Cheboygan | MI | Sand |
| St James | MI | Sand |
| Port Wing | WI | Sand |
| Cornucopia | WI | Sand |
| Bayfield | WI | Sand |
| Ashland | WI | Sand |
| Saxon | WI | Sand |
| Oconto | WI | Sand |
| Pensaukee | WI | Sand |
| Big Suamico | WI | Sand |
| Sturgeon Bay Canal | WI | Sand |
| Algoma | WI | Sand |
| Two Rivers | WI | Sand |
| Manitowoc | WI | Mixed |
| Port Washington | WI | Mixed |
| Kenosha | WI | Mixed |
| Michigan City Harbor | IN | Sand |
| Rochester | NY | Mixed |
| Sandusky | OH | Mixed |

Source: Great Lakes Commission

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Geological Engineering    Civil & Environmental Engineering

# Beneficial Use of Dredged Materials in Great Lakes Commercial Ports for Transportation Projects

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*Center for Logistics, Trade and Transportation Symposium*

*February 27, 2014, Gulf Port, MS*

C F I R E
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University of Wisconsin-Madison    Slide 1

## Motivation

- Dredged material (DM) management options for Great Lakes (GL) commercial ports are diminishing
- Many existing disposal facilities at or near capacity
- High costs, limited new site availability
- At least 6 GL high-cargo ports in "critical" status
  - severely restricted channel availability within 5 years
- Another 6 have "pressing" needs
  - restricted channel availability within 10 years

Source: USACE, 2012

University of Wisconsin-Madison    Slide 2

# Dredged Material (DM) Management

1) Open water placement
2) Capping (Subaqueous, Upland)
3) Beach nourishment
4) Confined disposal facilities (CDF)
5) Beneficial Use

Open water placement

beach nourishment

CDF

Images: J. Miller, 1998, Confined disposal facilities on the Great Lakes



# Great Lakes CDFs


Figure 7. Manitowoc CDF

- 23 of 44 filled or at less than 10% capacity (1998)
- Approximately 4.7 years to fill current capacity without further withdrawals. (Great Lakes Commission)

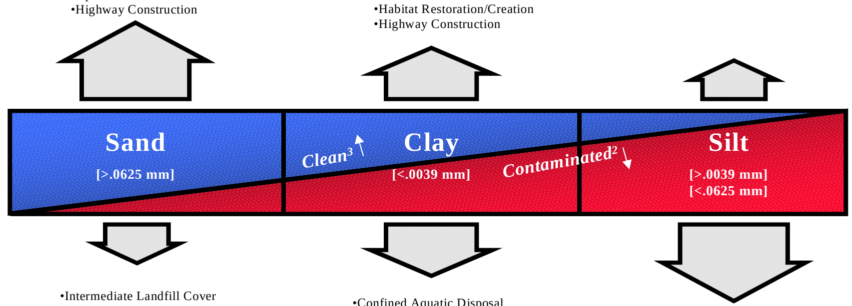
Sources: J. Miller, 1998, Confined disposal facilities on the Great Lakes
Great Lakes Commission (http://glc.org/rsm/faq.html)

## *What Happens to Our Dredged Material?*

- Manufactured Soil
- Aggregate
- Intermediate Landfill Cover
- Ocean Disposal
- Beach Nourishment[1]
- Habitat Restoration/Creation
- Upland Fill
- Highway Construction

- Manufactured Soil
- Ocean Disposal
- Landfill Final Cap
- Landfill Liner
- Upland Fill
- Nearshore Fill
- Brownfield Cover
- Habitat Restoration/Creation
- Highway Construction

- Upland Fill
- Brownfield Cover
- Habitat Restoration/Creation
- Nearshore Fill
- Manufactured Soil
- Highway Construction




- Intermediate Landfill Cover
- Confined Aquatic Disposal
- Confined Upland Disposal
- Upland Fill
- Nearshore Fill (with Capping)

- Confined Aquatic Disposal
- Confined Upland Disposal
- Nearshore Fill (with Capping)
- Landfill Cap (with Clean Cover)
- Brownfield Cap (with Clean Cover)
- Mine Reclamation

- Confined Aquatic Disposal
- Confined Upland Disposal
- Nearshore Fill (with Capping)
- Landfill Intermediate Cover
- Mine Reclamation
- Brownfield Cap (with Clean Cover)
- Decontamination and Disposal

[1] 75% Sand; grainsize distribution must be equivalent to existing conditions
[2] Uses assume no decontamination
[3] Uses assume clean or decontaminated

Source: NJDOT/OMR



# Project Objectives

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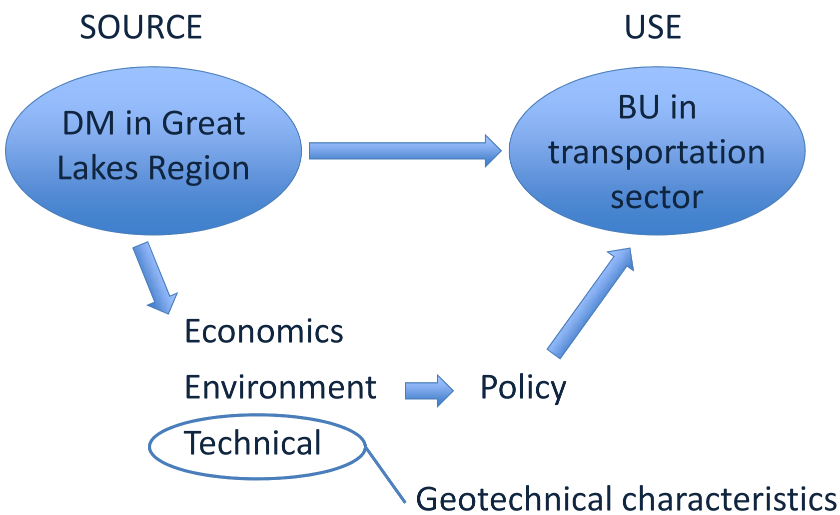
Develop framework to link together:

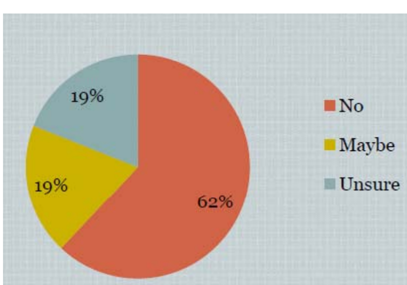
1) Applications for BU of DM in transportation sector
2) Required geotechnical properties
3) Geotechnical laboratory and field methods
4) Quantitative specifications for trans. applications
5) Locations in Great Lakes region where sourced



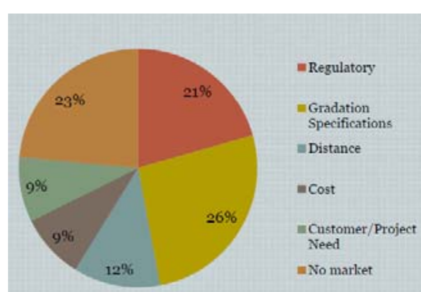



# Challenges

Would you consider DM as substitute for traditional material sources?




Why not?



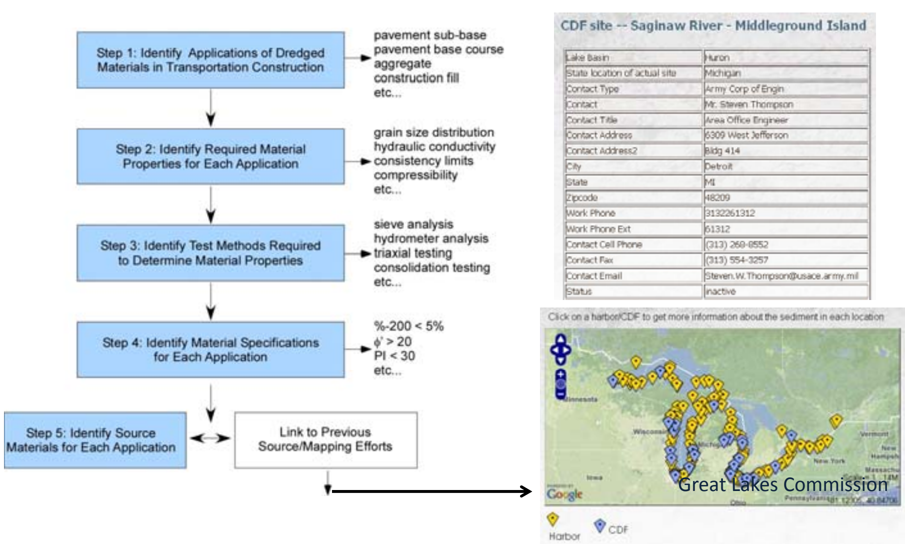

Source: J. Curran, Beneficial Use of Dredged Material from CDF Summit (NJDOT/OMR, 2009)

## Opportunities

- Beneficial use of DM alone or in mixtures with industrial byproducts could have major impact solving the declining disposal capacity as well as environmental benefits.
- The greatest energy and green house gas emissions are in production of materials used in construction of transportation structures.  Avoiding this step by using DM instead of natural mined materials will contribute to sustainable construction.



## Project Framework



# Task 1: Identify Potential Applications in Transportation Sector

- Document success stories and case histories
  - performance metrics, cost savings, life cycle analysis
- Develop matrix of potential transportation applications
  - coarse-grained (e.g., structural fill, backfill, aggregate)
  - fine-grained (e.g., fill, geotube infill, topsoil)
  - amended (e.g., cement, fly ash, CKD, RCA/RAS)



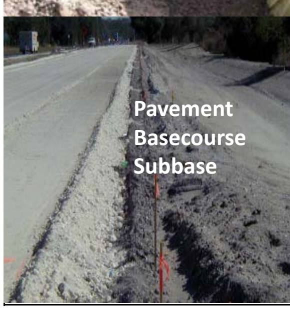
# Tasks 2-4: Identify Relevant Material Characteristics, Methods, and Specifications

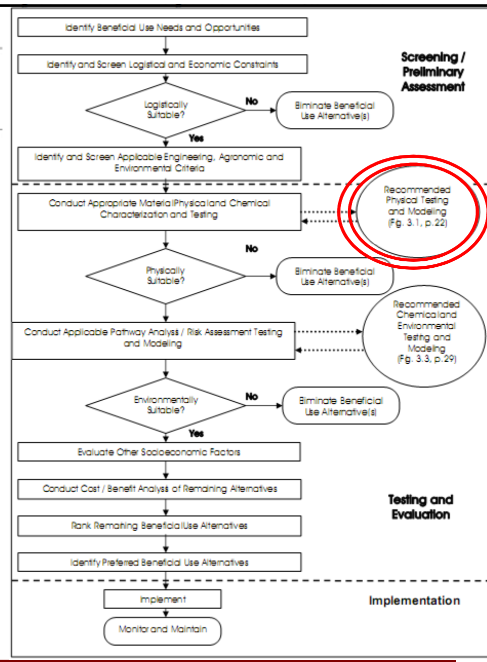
- Barriers to optimal use of DM for beneficial use include an inconsistency between screening metrics (e.g., grain size) and the way they can be applied (Brandon and Price, 2007).
- Requires understanding of design elements of transportation systems (geotechnical & structural)
- What characteristics are important for specific applications?
- How can these be measured?
- What are quantitative specifications?

# Geotechnical Characteristics: The "Big Four"

1) Classification and Index Properties
   - grain size distribution, grain shape, percent fines
   - plasticity, mineralogy
   - compaction characteristics
2) Strength
   - undrained shear strength (short term)
   - drained shear strength (long term)
3) Compressibility
   - elastic settlement, consolidation settlement, modulus
4) Hydraulic Conductivity
   - saturated conductivity, water retention (drainage)



| Transportation Sector Application | Required Material Characteristics | Geotechnical Testing Metrics |
|---|---|---|
|   | 1. Freely draining<br>2. High strength<br>3. Efficient compaction<br>4. Free from rocks, large or frozen lumps, wood, or other unsuitable material.<br>5. Electrochemical considerations | 1. Grain size distribution<br>2. Compaction characteristics<br>3. Shear strength<br>4. Permeability/Drainage<br>5. Freeze-thaw susceptibility |
|   | 1. Freely draining<br>2. High strength (cyclic load)<br>3. Sufficient stiffness<br>4. Efficient compaction<br>5. Large amounts of material | 1. Grain size distribution<br>2. Compaction characteristics<br>3. Resilient Modulus<br>4. California Bearing Ratio(CBR)<br>5. Shear Strength<br>6. Permeability/Drainage |




# Tasks 5: Link Source to End Use


http://glc.org/rsm/mapholder.html

### CDF site -- Kenosha Harbor

| | |
|---|---|
| Lake Basin | Michigan |
| State location of actual site | Wisconsin |
| Contact Type | Army Corp of Engin |
| Contact | Mr. James Bonetti |
| Contact Title | Area Office Engineer |
| Contact Address | 124 North Main Street |
| Contact Address2 | |
| City | Kewaunee |
| State | WI |
| Zipcode | 54216 |
| Work Phone | 9203883720 |
| Work Phone Ext | 83712 |
| Contact Cell Phone | (920) 889-0738 |
| Contact Fax | (920) 388-2058 |
| Contact Email | James.A.Bonetti@usace.army.mil |
| Status | inactive |
| Remaining active capacity of CDF (cubic yards) | 0 |
| Average Amount Material Received Annually at CDF (cubic yards) | 25000 |
| Est volume material available for removal / ben use at CDF (cubic yards) | 0 |


- geotechnical characteristics
- suitable for…..
- recommended for….

http://glc.org/rsm/mapholder.html



## Ongoing Work

- Quantitative analysis to flesh out the framework
  - Testing at select Great Lakes CDF sites
  - Amended materials
- Develop end-use matrix
- Site Characterization (CDF Heterogeneity)
- Link to readily accessible web format

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