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Laboratory Study Geotechnical Benefits of Mixing Construction and Demolition Screenings with Cement-Amended Dredged Materials

FINAL REPORT
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16. Abstract

A laboratory study was performed to assess the geotechnical benefits of mixing construction and demolition screenings ("CDS") with cement-amended dredged materials. Different sample mixes were prepared and tested for geotechnical characteristics. Soil index properties, drying curves, permeability, consolidation, swell, compaction, and strength were determined.

Based on the results of this study, it can be concluded that the mix of CDS and dredged materials has similar engineering properties to those of the dredged materials. Nevertheless, the final product has lower water content than the stabilized dredged material ("SDM"), making it easier to compact and more manageable.

Structurally, the strength of the material is reduced slightly with the addition of CDS. However, this reduction is not significant for normal structural applications. With the addition of CDS to dredged materials, the permeability of the soil media increases, thereby making it more suitable for structural fills. Compaction, consolidation, and swell conditions of the mix are similar to those of the original SDM.

The authors of this study recommend the field mixing of CDS and SDM provided that additional field testing is conducted to determine the most suitable mixing procedures before implementation. It is also recommended that to avoid any reduction in strength, CDS be mixed with SDM at proportions not to exceed 20 percent. During the implementation, a monitoring plan should be designed to better determine and/or confirm the actual geotechnical conditions of the soil media in the field.

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ABSTRACT

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1. INTRODUCTION

This study was performed as part of a research effort to evaluate an alternative beneficial use for dredged material. Specifically, this project focused on assessing the geotechnical benefits of mixing construction and demolition screenings ("CDS") with stabilized dredged material ("SDM"). This document summarizes the results of that assessment.

This research project was conducted by the Department of Civil and Environmental Engineering at Rutgers University with the technical assistance of Icon Engineering, Inc. The project was directed by Eugenio Giraldo, Ph.D., Visiting Profesor, and by Ali Maher, Ph.D, Chairman of the Civil and Environmental Engineering Department at Rutgers University. Nestor Soler, P.E of Icon Engineering, and Farhad Jafari, P.E. of OENJ-Cherokee Corporation provided technical assistance during the different phases of the study.

2.0 PROJECT SCOPE OF WORK

The project was designed to evaluate, preliminarily, the benefits of mixing SDM with CDS. The research project consisted mainly of the following activities:

- Evaluation of available data on CDS and SDM;
- Material selection and mixing;
- Geotechnical testing; and
- Analysis and evaluation of results

3.0 EVALUATION OF AVAILABLE DATA

3.1 BACKGROUND

SDM and CDS are currently used as fill materials at brownfield sites, provided that the permitted sites have proper environmental controls and that each of these materials is processed prior to placement. Following is a general description of CDS and SDM.

Construction and Demolition Screenings

CDS originates from the separation of recoverable recyclables, including metal, masonry, large wood pieces, shingles and other recyclables from mixed construction and demolition waste. Following this initial separation, the remaining materials are screened using either a trommel screen or vibrating screen. Materials that pass through a ½"-screen are designated as CDS. Based on available field measurements during CDS disposal at brownfield sites, the average content of wood in CDS is approximately 10% (± 4%) by weight, which equates to approximately 25% wood by volume. The Total Organic Carbon (TOC) ranges from a minimum of 9% to a maximum of 15.6%. CDS densities are in the range of 90 lbs/ft^3.

Significant quantities of CDS are generated in the New Jersey and New York metropolitan area. CDS is currently being sent to recycling facilities or placed at permitted brownfield sites.

Dredged Materials

In order to improve marine traffic, sediments are routinely dredged from the New York and New Jersey marine ports. These dredged materials generally consist of silt materials with some sand and organic material fractions. Currently, these dredged materials come from maintenance dredging operations at the Hudson River, Kill Van Kull, Newark Bay, and Port Elizabeth. Due to the environmental quality of the dredged materials, some of these sediments cannot be disposed of in the ocean and are currently being placed at permitted brownfield sites. Specifically, the USEPA Region II has established three categories for ranking dredged materials based upon their suitability for ocean disposal. Category III dredged materials have been defined as sediments that do not meet the ocean dumping criteria due to their environmental quality. These materials are disposed of at permitted upland facilities. Dredged sediments without amendment or stabilization are commonly referred as Raw Dredged Materials (RDM).

The RDM that are designated for upland disposal are usually amended with certain admixtures (e.g. cement, fly ash, and/or lime), and placed or compacted using specific procedures. The processing and handling of the RDM depend upon the quality of these materials, the permit requirements, and the end-use of the land on which they are being placed.

Upon dredging, the RDM is loaded onto a barge and transported to the processing facility —generally a plant with screens, sorters, and pugmills— where the material is stabilized by amending it with admixtures in a pug mill. Amending the RDM with admixtures enhances the workability of the material by decreasing its water content and thereby making it easier to transport, spread, disk, grade, and compact. It has also been found that, under certain conditions related to processing and placement, the addition of admixtures to the RDM reduces the leachability of certain contaminants. The amended dredged materials are generally referred to as SDM, or stabilized dredged materials.

Significant quantities of Category III materials are dredged from the New Jersey and New York harbor area. These materials are processed and disposed of at permitted brownfield sites.

3.2 PREVIOUS STUDIES

Prior studies have evaluated either the use of cement to stabilize RDM, or the options for disposing of CDS. However, a study that focuses on the mixing of CDS and dredged materials has not yet been reported in the technical literature, to the best knowledge of the authors of this report.

During the initial phase of this project, the following studies were reviewed:

- The geotechnical effects of mixing cement-based additives to RDM have been studied by several authors in recent years. Vaghar et al., 1997, studied the stabilization of dredged sediments from Boston's inner harbor as part of the Central Artery-Tunnel Project. Six stabilization mixtures were tested. These included materials such as quick lime, fly ash, ferric chloride and calcium chloride. The main objective was to achieve a workable mixture of dredged materials with an initial minimum strength of 400 psf, and a final minimum strength of 1500 psf. All of the six treatments reached the minimum final strength requirement. However, the study recommended the use of quick lime due to the rapid increase in the material's workability, a condition necessary for the efficient placement of dredged materials in the field.

- Maher et al., 1998, performed a geotechnical evaluation of dredged sediments from the Port of New York and New Jersey using materials such as Portland cement, lime kiln dust, and cement kiln dust to stabilize the RDM. The highest strength in an unconsolidated undrained triaxial test was obtained using Portland cement in 7.5% by wet weight proportion, as compared to additions of 20% of cement kiln dust or 20% of lime kiln dust.

- Takashi, Porbana and Yamane, 2001, studied the material properties of sediments from the Tokyo Bay after the sediments had been amended with cement and a light-weight aggregate. Mixtures of RDM amended with 10% and 20% cement were tested, as were aggregate mixtures. The engineering properties of the material were determined using unconfined compression, direct shear and consolidation tests. The material mixtures were allowed to cure undisturbed and core samples of the materials were taken for analysis.

- Tremblay, Leroueil and Locat, 1999, noted the improvements in vertical yield stress in soils and dredged sediments from the Port of Quebec after the addition of hydrated lime and Portland cement. Portland cement, in ratios of 2%, 5% and 10% by dry weight, was added to the soils and dredged sediments. The mixtures were then subjected to one-dimensional compression tests, and a general pattern was observed. A predictive model for vertical yield stress, void ratio and additive content was developed for the soils and sediments tested.

- Boutouil and Levacher, 2001, experimentally studied the pore structure of dredged sediments that had been stabilized with different amounts and types of cements. The porosity of the stabilized materials ranged from 40% to 75% and increased in the case of air-dried mixtures, and decreased with a reduction in the water-cement ratio. A characteristic peak in the pore size structure is observed in the 0.01um size.

3.3 PRELIMINARY EVALUATION OF PREVIOUS STUDIES

A review of previous studies and an evaluation of field activities at sites where CDS and dredge have been disposed of revealed the following:

- CDS is characterized by relatively low density, and low initial water content when compared with dredged materials.
- Initially, dredge has a high water content, which produces complications with handling the material in the field. Experience with material that was amended with 8% cement revealed that during the stabilization, stockpiling, and aeration phases SDM has to be worked extensively or stored for long periods of time in order to allow for proper handling and compaction.
- When SDM is placed, spread, and disked for the purpose of drying, its strength may be compromised. This may result when the bonds created by the additives are broken.
- The strength of the SDM after processing and placement has generally been found acceptable for structural fill. However, its low permeability may limit its applicability for some applications.

4. MATERIALS AND METHODS

4.1 SAMPLING

Samples of the SDM and CDS were collected at the OENJ site in Bayonne, New Jersey. The placement of both materials, SDM and CDS, is permitted at the OENJ-Cherokee Bayonne site. At this site, the geotechnical and environmental conditions of the structural fill have been evaluated and the fill is considered appropriate for the end-use of the property.

Both raw and stabilized dredged materials were collected directly from the barges and from the pug mill, respectively. Immediate after the samples were collected, they were transported to the laboratory in sealed containers. In the laboratory the samples were homogenized and aliquots were taken for water content analysis. Samples of CDS and SDM were immediately mixed according to the following proportions:

	CDS	RMD	Cement	SDM
CDS	100%			
SDM (by weight)		92%	8%	
40% CDS : MIX 1 (by weight)	40%			60%
20% CDS : MIX 2 (by weight)	20%			80%

4.2 DRYING AND CURING OF MIXTURES

Once the samples were prepared according to the proportions specified above, mixtures were allowed to cure and dry undisturbed in open plastic containers. Samples from each mix were tested for water content to study the changes in water content over time.

4.3 GEOTECHNICAL PROPERTIES

Sample Classification

Samples from each mix, including SDM, were tested for geotechnical index properties. Sieve analysis and Atterberg limits, including a hydrometer test and water content analysis, were performed for each mix according to ASTM procedures.

Compaction Tests

When the samples arrived at the laboratory, they were too wet for compaction tests, and thermal drying was not recommended because it may have affected the cementitious bonds of the amended dredge.

After the materials were cured and dried for over 30 days, representative samples for each mix, including SDM, were subject to compaction tests using ASTM protocol D-1557.

Unconfined Compression Tests

Once the samples reached the optimum water content, as determined by the compaction tests, unconfined compression tests were performed on representative samples for each mix following the ASTM protocol D-4219. The unconfined compression test is a special case of the unconsolidated undrained triaxial test, and it is used to determine compressive strength q_u. Some authors estimate that at best the compressive strength obtained from unconfined compression tests is no more than about 80% of the true strength.

Permeability and Consolidation Tests

Consolidation and permeability tests were also performed on the representative samples form each mix following the ASTM protocol D-2435, and D-5084.

5. RESULTS

5.1 CLASSIFICATION AND INDEX PROPERTIES

A summary of the soil characterization for each mix is presented in Table 1. All samples were classified as A-7-5 and MH according to the AASHTO and USCS systems, respectively. Data obtained in the laboratory to determine the classification and Index properties are presented in Attachments A-1 and A-2.

The addition of CDS to the SDM does not change the classification of the 20%CDS and 40%CDS samples in any of the systems of classification. However, as the amount of CDS increases, there is a marginal decrease in the clay content and an increase of the silt fraction.

Table 1 Summary of Soil Characterization

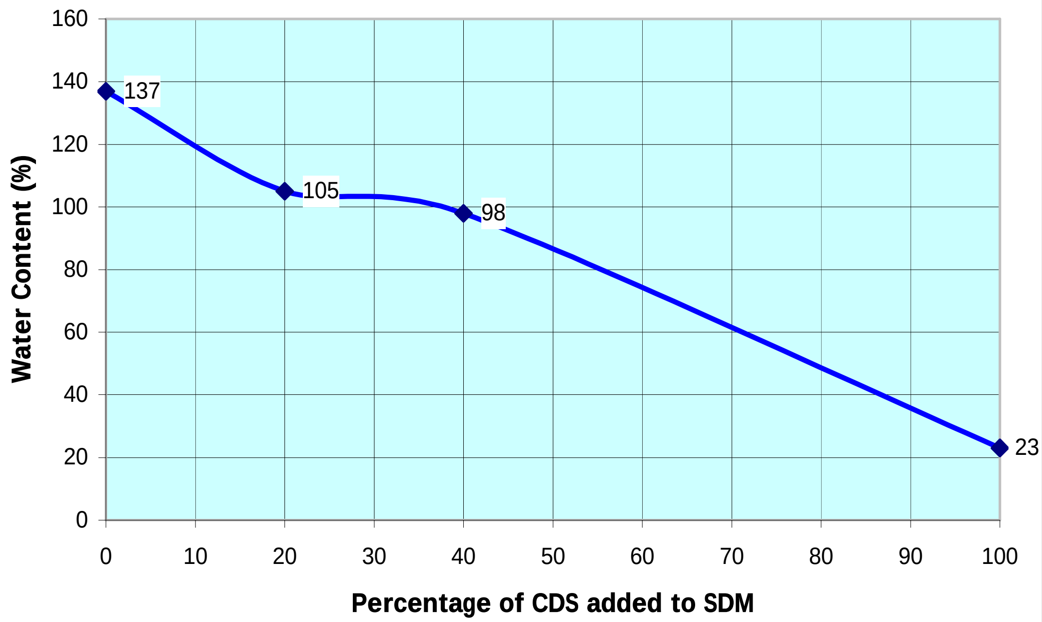
Sample	Specific Gravity	Liquid Limit (% moisture)	Plastic Limit (% moisture)	Silt Content (%)	Clay Content (%)
SDM	2.584	65.0	46.3	63.2	25.7
20% CDS	2.613	58.8	NP (1)	65.1	22.7
40% CDS	2.626	60.5	NP	65.6	21.6

(1) NP: Non-Plastic

5.2 INITIAL WATER CONTENT

Figure 1 presents the effect of mixing CDS with SDM on the initial water content of the material.

Figure 1
Intial Water Content vs Percentage of CDS

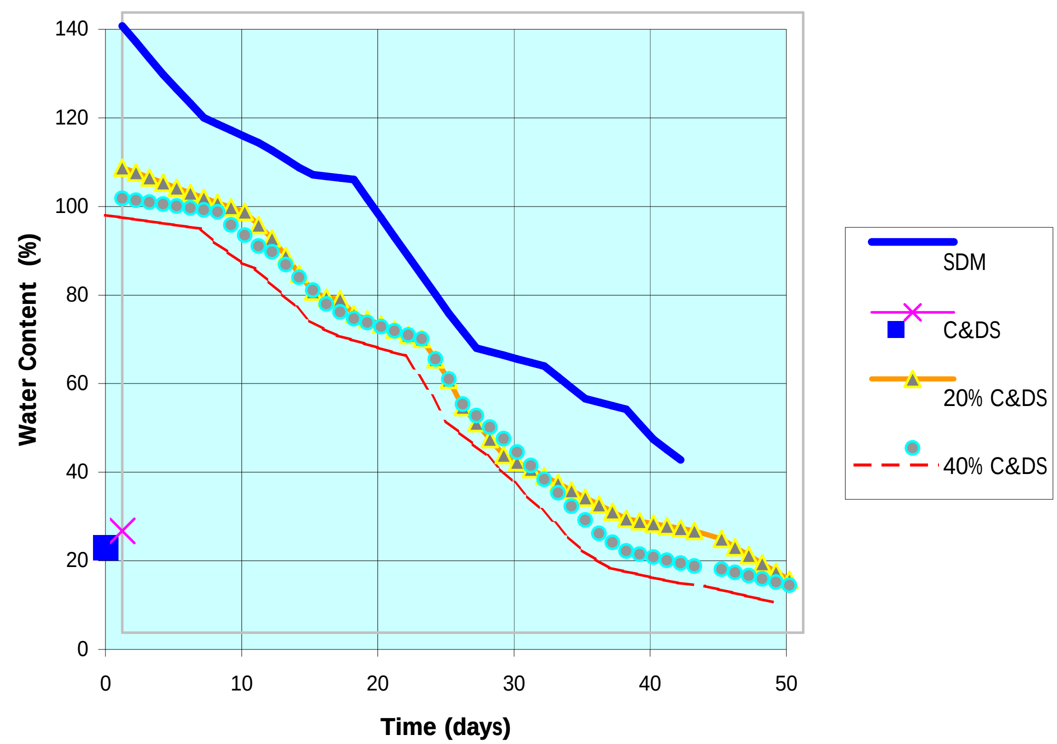


CDS has a lower moisture content than does SDM, so that a mixture of both materials produces a soil that is drier than SDM alone. In the 40%CDS mixture, the moisture content of SDM, approximately 140%, was reduced by 40%. It is clear that the addition of CDS to SDM significantly enhances the workability, handling and placement of the material in the field. In addition, by adding CDS to SDM, the potential leachability of the soil matrix would be reduced, thereby avoiding the migration of cement particles in water and enhancing the curing properties of the mix.

5.3 DRYING CURVES

As the mixes were allowed to dry in the laboratory, the water content was monitored over time (refer to Attachment A-3). Based on these data, drying curves for different treatments were developed, a summary of which is presented in Figure 2.

Figure 2
Drying Curve for Different Treatments

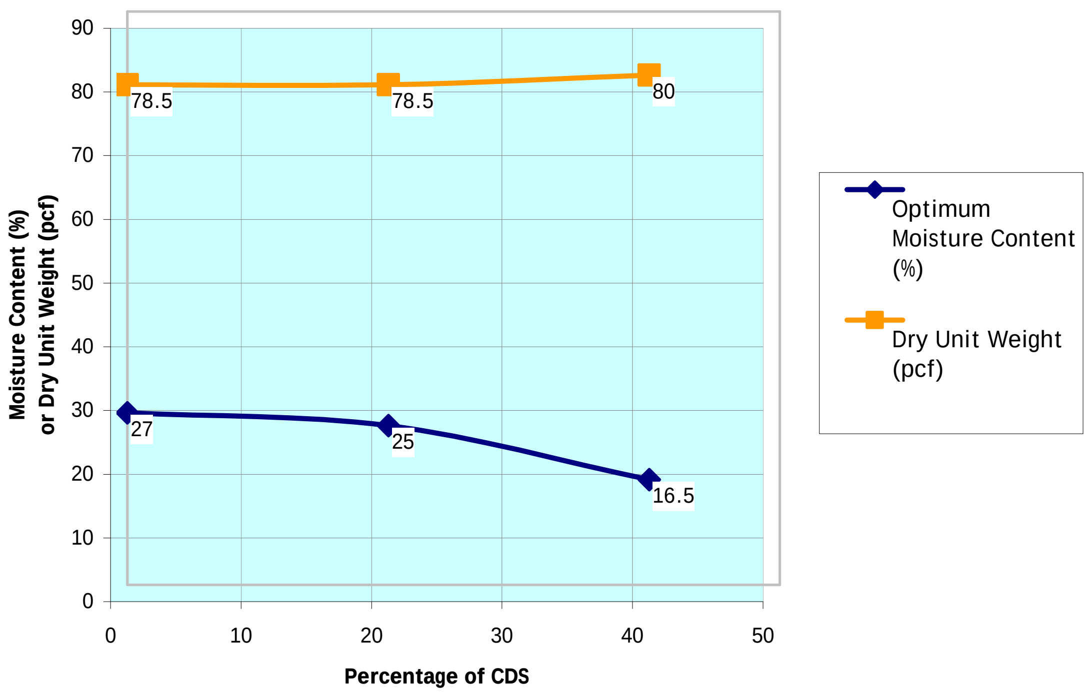


As evidenced in Figure 2, the initial decrease in moisture content that occurs as CDS is added to SDM is maintained over time. This effect suggests that the benefits gained by decreasing the initial moisture content are also maintained over time.

5.4 Compaction Tests

The results from the compaction tests and complete laboratory data are presented in Attachment A-4. To compare the effects of CDS in the different mixes, the optimum water content and maximum dry density from each test were compared with the proportions of CDS in the mix. Figure 3 presents this analysis.

Figure 3
Optimum Moisture - Maximum Density Relationship
for Differente CDS and SDM Mixes

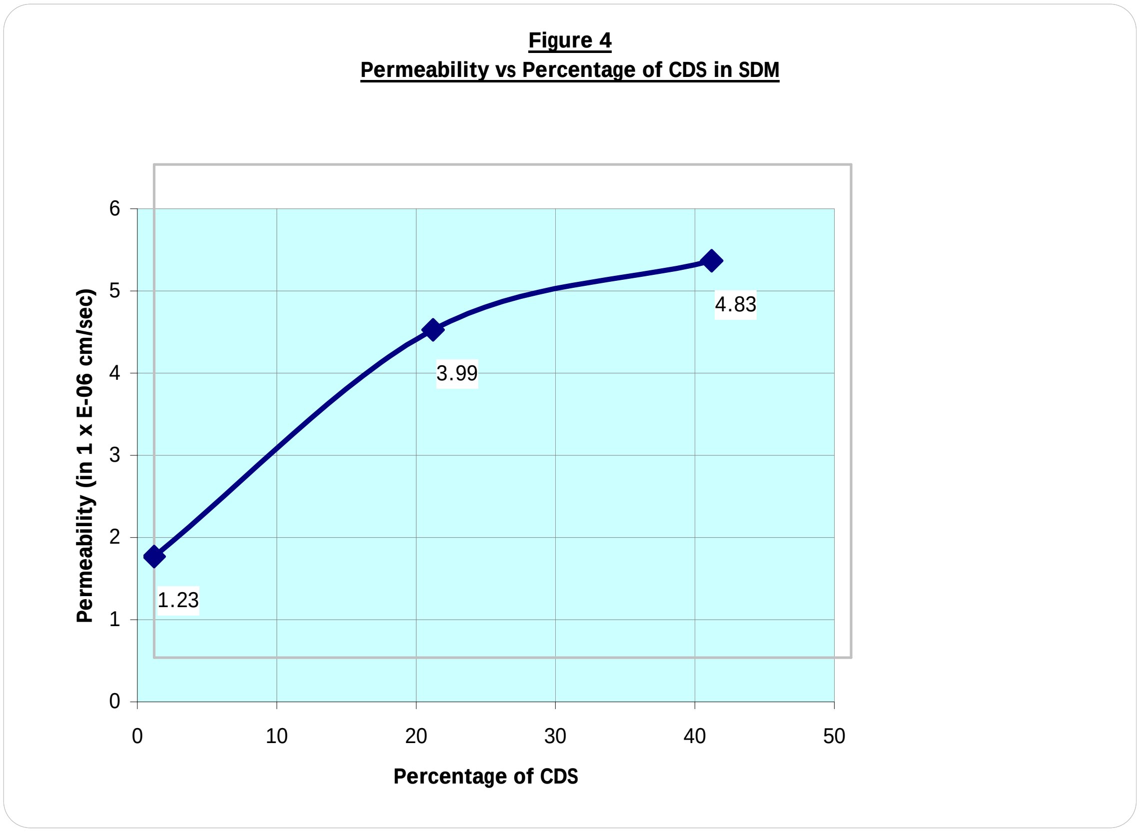


As indicated in Figure 3, the maximum dry unit weight increases slightly as the fraction of CDS increases in the mix. Moreover, there is a marginal decrease in the optimum moisture content when the percentage of CDS is in the 0 to 20% range. When the percentage of CDS increases to the 40% range, the optimum moisture content decreases more markedly.

As presented in Figure 3, the optimum water content decreases by approximately 10% when 40% CDS is added to SDM. This effect, on the other hand, has to be compared with the decrease in moisture content that results from the lower amount of water present in the CDS. The optimum water content necessary to achieve maximum dry density can be reached more quickly in the 40%CDS samples, a reduction which is maintained over time.

5.5 HYDRAULIC CONDUCTIVITY, CONSOLIDATION, AND SWELL TESTS

The results from the permeability tests and complete laboratory data are presented in Attachment A-6. Figure 4 presents the effects that increasing amounts of CDS have on the permeability of the soil media. As evidenced in Figure 4, higher proportions of CDS increase the hydraulic conductivity of the mixture. Higher hydraulic conductivity is desirable for certain applications such as structural fill.



Similarly, the results of the swell and consolidation tests are presented in Attachment A-7. A summary of the test results is presented in Table 2. The compression and swell indexes, obtained in the laboratory from the e-log p curve (void ratio vs. logarithm of pressure), are parameters normally used for the calculation of time-dependent settlements in the field. Review of laboratory results indicate that adding CDS to dredge does not significantly change or affect the consolidation and swell properties of SDM.

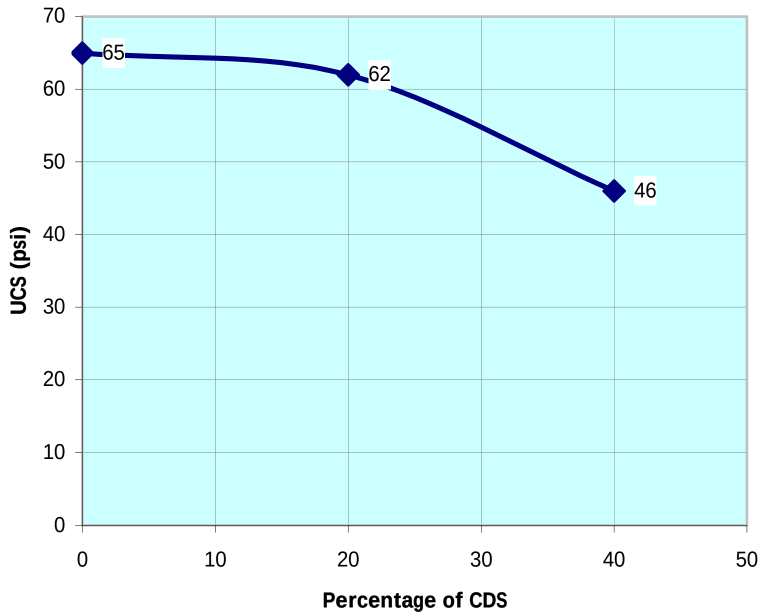
Table 2 Summary Consolidation and Swell Test

Sample	Compression Index (Cc)	Swell Index (Cs)	Initial void ratio (e_o)	Cs/Cc
SDM	0.22 0.25	0.02 0.02	1.289 1.308	0.09 0.08
20% CDS	0.19 0.20	0.01 0.01	1.253 1.252	0.05 0.05
40% CDS	0.24 0.18	0.02 0.01	1.313 1.262	0.08 0.05

5.6 STRENGTH

The effects that increasing amount of CDS have on the unconfined compressive strength, UCS, are presented in Figure 5. It can be observed that when the mixtures contain less than 20% CDS, the effect on the UCS is not significant, while in mixtures with larger proportions of CDS there is a slight decrease in the strength. However, the range of measured strength is sufficient for applications such as embankments and structural fills. The results from the strength tests and complete laboratory data are presented in Attachment A-5.

Figure 5
Unconfined Compressive Strength vs Percentage of CDS



6. CONCLUSIONS

Based on the results of this study, it can be concluded that the mix of CDS and dredged materials has similar engineering properties to those of the dredged materials. Nevertheless, the final product has lower water content than SDM, making it easier to compact and more manageable. Structurally, the strength of the material is marginally reduced with the addition of CDS. However, this reduction is not significant for normal structural applications. With the addition of CDS to dredged materials, the permeability of the soil media increases, thereby making it more suitable for structural fills.

Conclusions from this preliminary study are outlined below:

- The addition of CDS improves the workability of the dredge by reducing the water content of the SDM.

- By reducing the water content of the mixture at the processing stages, field handling and drying is facilitated, thereby preventing strength losses, and reducing construction delays associated with the aeration and drying of SDM.

- The addition of CDS increases the permeability of the SDM. The addition of calcium ions present in the CDS may exchange sodium ions present in the dredge, thereby improving the potential for particle aggregation, flocculation, and water mobility.

- Compaction, consolidation, and swell conditions of the mix are similar to those of the original SDM.

In summary, this study reveals that there are no geotechnical disadvantages resulting from the addition of CDS to SDM. The authors of this study recommend the field mixing of CDS and SDM provided that additional field testing is conducted to determine the most suitable mixing procedures before implementation. It is also recommended that to avoid any reduction in strength, CDS be mixed with SDM at proportions not to exceed 20 percent. During the implementation, a monitoring plan should be designed to better determine and/or confirm the geotechnical conditions of the soil media in the field.

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