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Project Summary Report 1874-S
Assessment of Cohesionless Materials to Be Used as Compacted Fill
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PROJECT SUMMARY REPORT

Recommended Compaction Requirements for Placement of Uniform Fine Sand Backfill Materials

Objective and Scope of Project

The objective of this project was to develop recommendations for compaction of cohesionless soils used as backfill materials. The Texas Department of Transportation (TxDOT) utilizes a number of sources of cohesionless soils as fill materials for embankment construction and as backfill for mechanically stabilized earth (MSE) walls. Some problems have been experienced with these materials in the past, especially with settlements of backfills behind retaining walls. TxDOT sought a suitable procedure for placement of these materials that would ensure satisfactory performance.

What We Did...

Survey of State Department of Transportation Compaction Requirements

Most of the state departments of transportation (DOTs) in the United States were surveyed regarding their requirements for compaction of cohesionless fill materials. Particular attention was paid to the laboratory compaction procedures used and the specifications for field compaction.

Selection of Soil for Testing

TxDOT selected several sources of cohesionless fill materials for testing and evaluation. Initially, attention was focused on the El Paso area where abundant sources of cohesionless fill materials are available and used. Nine sources of fill material were identified in the El Paso area and samples were obtained for further laboratory testing. After the initial selection of soils from the El Paso area, the study scope was widened to include soils from the Houston, Fort Worth, Beaumont, Corpus Christi, and Austin regions. Fourteen different cohesionless fill materials were selected for study. Samples of each of these soils were obtained for further laboratory testing.

Laboratory Testing Program

Laboratory testing included basic index properties and grain size distribution for classification of each soil. Most of the soils were compacted using each of the following compaction procedures:

- TxDOT Tx 113-E-Laboratory Compaction Characteristics and Moisture-Density Relationship of Base Materials
- ASTM D 1557-Laboratory Compaction Characteristics of Soil Using Modified Effort
- British Standard BS-1377 -Vibrating Hammer Method
- ASTM D 4253-Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

All tests using the Tx 113-E procedure were performed using a special hammer and neoprene pad recommended in the Tx 113-E test procedure for “materials difficult to compact.” For all soils compacted using the ASTM D 4253 procedure, the minimum density was also determined using the ASTM D 4254 test procedure (minimum index density and unit weight of soils, and calculation of relative density). The maximum and minimum densities determined by

ASTM D 4253 and 4254 procedures were used to calculate relative densities for the soils tested. In most cases, complete moisture-density curves were obtained for each soil using the compaction procedures listed above.

Grain size distributions were determined for samples of many of the soils before and after compaction to determine if any significant particle breakage occurred during the compaction process.

Several soils were selected for additional testing to determine the amount of compression produced when the soils were subjected to load and, subsequently, inundated with water. The objective of these tests was to determine what compaction levels were required to reduce post-construction settlements of the fill materials to acceptable limits.

What We Found...

1. A review of other states' DOT compaction requirements revealed that none of them used relative density (American Society for Testing and Materials (ASTM)) as a basis for specifying compaction of cohesionless fill materials. Although relative density is generally thought to be the best indicator of degree of compactness for cohesionless fill materials, relative density does not seem to be used much for compaction control. Relative density is difficult to determine and great care is required to obtain reproducible results. Because of the complexity and difficulties involved, relative density is apparently not used.
2. Most DOTs use either the standard proctor (ASTM D 698) or modified proctor (ASTM D 1557) compaction procedures for specifying field density requirements for cohesionless soils. Standard proctor compactive effort is used more commonly than modified proctor compactive effort.
3. Most of the soils selected by TxDOT and tested in this study were uniform fine sands. Six of the soils were classified as SP (poorly graded sand) by the unified soil classification system. Two of the soils were classified as SM (silty sand) soils. Finally, six more of the soils were classified by the dual classification symbols as SP-SM soils.
4. Many of the soils showed no distinct optimum water content; the moisture density curves were flat with no pronounced peak. This was especially true for the soils classified as SP and SP-SM soils.
5. For most of the soils tested, no significant change in grain size distribution was observed after compaction, indicating that particle breakage was minimal. Except for one soil, the percent increase in particles by weight passing the No. 200 sieve was less than 4 percent. Only one soil described as "caliche" showed a larger change in grain size distribution because of compaction; for this soil, the percent by weight passing the No. 200 sieve increased by approximately 9 percent.
6. The modified proctor (ASTM D 1557) compactive effort produced maximum dry unit weights that met or exceeded the maximum density obtained by the ASTM D 4253 procedure for ten of the fourteen soils tested. For the four soils that showed lower densities by the modified proctor procedure, the densities were no less than 3 percent below the maximum density obtained by the ASTM D 4253 procedure. These results all indicate that the modified proctor maximum dry density represents a relatively high degree of compaction for cohesionless soils like the ones tested.
7. The Tx 113-E compaction procedure produced maximum dry unit weights that in all cases exceeded the maximum dry density determined by the ASTM D 4253 test procedure. The densities determined by the Tx 113-E procedure ranged from approximately 1 to 16 percent higher than the densities tested by the ASTM D 4253 procedure. These results indicate that the Tx 113-E compaction procedure produces a very high degree of compaction for cohesionless soils like the ones tested in this study.
8. Tests on six of the soils using the British vibratory hammer showed dry unit weights that ranged from about 3 to 10 percent greater than the ASTM D 4253 maximum density. These results confirm that the British vibratory hammer also produces a relatively high degree of

compaction in cohesionless soils.

9. It is difficult to maintain a constant, consistent compactive effort with the British vibratory hammer, and the test was judged to be the most difficult of the compaction procedures investigated. Because of the difficulty and lack of widespread use in Texas, the procedure was not used for all soils and was considered less suitable than the other procedures used on practical grounds.
10. The version of the Tx 113-E compaction procedure that uses a special ram and neoprene pad over the surface of the soil does not seem to be widely understood and used by TxDOT. The procedure was judged to be more complex and difficult to use than the modified proctor (ASTM D 1557) procedure. Obtaining good, consistent results among laboratories with the Tx 113-E procedure may be much more difficult than with the modified proctor (ASTM D 1557) procedure.
11. There is a noticeable variation in vertical dry unit weight in the compaction mold for the modified proctor compaction test and this may explain why the dry unit weight for several of the soils tested was slightly less than the maximum density obtained by the ASTM D 4253 procedure. This was particularly noticeable for the sands containing very few fines, i.e., the soils classified as SP soils. However, the variation in density does not seem to be sufficient to adversely affect the use of the modified proctor (ASTM D 1557) compaction test for control of densities in compacted fills.
12. In one instance where cohesionless fills were observed being compacted in the field and difficulties were encountered, it was observed that two different nuclear density gauges were giving grossly inaccurate results. Both gauges indicated dry unit weights that were substantially less than the actual dry unit weight as determined when using other measurements of density.

The Researchers Recommend...

1. Suitable specification and control of compaction cohesionless fill materials can be achieved using either the modified proctor (ASTM D 1557) or Tx 113-E (with neoprene pad and special compaction hammer) procedures.
2. The modified proctor (ASTM D 1557) compaction procedure is preferred to the Tx 113-E procedure, because the ASTM procedure is simpler and more likely to be carried out properly by laboratories, both inside and outside TxDOT.
3. When the modified proctor compaction procedure is used for compaction specification and control, compaction to 95 percent of the maximum dry unit weight is recommended.
4. If the Tx 113-E compaction procedure (with neoprene pad and special hammer) is used to specify and control compaction, it is recommended that the soil be compacted to 92 percent of the maximum dry unit weight determined by the Tx 113-E procedure.
5. For cohesionless soils like the ones tested, if the compaction moisture density curve exhibits a well-defined peak and optimum water content, the soil should be compacted using a water content approximately equal to the optimum water content. If no well-defined peak in the moisture density curve is observed, the soil should be compacted with significant water, e. g., corresponding to 50 to 75 percent saturation or the maximum amount of moisture that can be retained. Adequate moisture is necessary to prevent significant postconstruction settlements, even with compaction to the levels recommended above.
6. These recommendations are based principally on tests performed on uniform fine sands classified as SP or SP-SM soils by the unified soil classification sytem. Some modifications may be appropriate for other soils, e. g., some SM soils and well-grained sands and gravels (SW, GW).
7. Procedures for calibration of nuclear gauges used for field density measurement and control should be reevaluated and carefully checked. In at least some instances, the nuclear gauges being used are not properly calibrated and are yielding erroneous results.

For More Details...

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The research is documented in the following reports:

Report 1874-1: *Evaluation of Laboratory Compaction Procedures for Specification of Densities for Compacting Fine Sands,* January 2001.

To obtain copies of a report: CTR Library, Center for Transportation Research, (512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status
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The research results recommend uniform fine sands be compacted to 95% modified proctor (ASTM D 1557) maximum dry unit weight for settlement-critical applications. It is expected this recommendation will be adopted and incorporated into the rewrite of the Texas Department of Transportation's Standard Specifications for Construction of Highways, Streets and Bridges.

For more information please contact Tom Yarbrough, P.E., RTI Research Engineer, at (512) 465-7685 or email at tyarbro@dot.state.tx.us.

Your Involvement Is Welcome!

Disclaimer

This research was performed in cooperation with the TxDOT and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement. The engineer in charge was Stephen G. Wright, P.E.

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