Earthworks_ A Guide, 2nd edition (PDFDrive)

Compaction

Compaction is the process by which soil particles are forced together by reduction of the air voids content

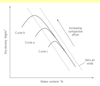
3 components

Soil or rock fill comprises three components:
solid (soil or rock particles)
water (leachate or other fluid)
air (or other gases).

Benefits

increase in density
increase in shear strength
reduction in compressibility
reduction in permeability

Optimum Water Content and Maximum Dry Density



When soil is really dry, it has high density, but you can compact it even more by adding some water. Water softens and lubricates the soil allowing for better compaction/higher density. But once you add too much water, you start to decrease the density and reduce compaction as the voids get filled with water instead

Optimum Water Content

The water content at which this occurs = the optimum water content (OWC).
[Point of which more water results in reduced compaction, not more]

Maximum Dry Density

corresponding dry density is termed the maximum dry density (MDD).

Tests

tests employ rammers to compact the soil; the rammers are of different masses (2.5 and 4.5 kg), fall from different heights and are applied to different numbers of soil layers in the mould.

A third test uses a vibrating hammer of known weight, vibrating at a known frequency for a known time period

- 2.5 kg rammer has been used for cohesive and fine grained granular soil
- 4.5 kg rammer for granular soils
- vibrating hammer for processed well-graded granular materials

Soil description and fill classification

Standards for classifying

- The description of soils is generally undertaken in accordance with BS EN ISO 14688-1 (BSI, 2002)
- Following laboratory testing procedures to determine the particulate grading, plasticity and any strength properties of the material, 'soil classification' is undertaken in accordance with BS EN ISO 14688-2 (BSI, 2004a)

most important assessment in any soil description is deciding whether the fill behaves as a 'coarse' (granular) soil or 'fine' (cohesive) soil

Fine = cohesive
Coarser= granular

Simple field test to determine if fine or coarse

A sample of the wet soil is remoulded, following the removal of cobbles and boulders.
If the soil sticks together and behaves in a plastic manner during remoulding, then it is described as a 'fine' soil (primary fraction being clay and/or silt).
Alternatively, if the material behaves in a coarse, non-plastic manner, then it is described as a 'coarse' soil (sand and/or gravel).

Fine soils thus need to be classified based on how the fill will behave, rather than simply applying predetermined criteria

- it is the engineering behaviour of the soil mass that determines the description of the soil

BS 6031 Cl 3.1 states that the engineering properties of the soil will differ between two major cases:

1. Soil assessed for geotechnical design (e.g. slope stability, settlement or bearing capacity):
fine (cohesive) soils include > 35% fines

2. Soil for engineered fill:
Fine (cohesive) soils include > 15% fines

Soil description text

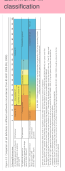
materials in upper case = the principal soil constituent (after the removal of any cobbles and boulders)

Materials in lower case = the nature and amount of any secondary materials

E.g

slightly sandy CLAY (sand-size particles present up to 35%)
sandy CLAY (sand-size particles present between 35 and 65%)
very sandy CLAY (sand-size particles present in excess of 65%).

Earthworks fill classification



BS 6031 (BSI, 2009)

Before, during & after excavation

classification of the same materials during excavation, transportation and deposition can vary, hence soil/fill may be classified at any of the following stages:

in situ – undisturbed condition prior to excavation;
on excavation – disturbed material after excavation;
on deposition – following placing and prior to compaction.

Plasticity

Plasticity of soil is its ability to undergo deformation without cracking or fracturing.

- A plastic soil can be moulded into various shapes when it is wet

Normally dictated by it's clay content

Engineering Properties:-
The main engineering properties of soils are permeability, compressibility and shear strength.
Permiability indicates facility with which water can flow through soils.
Compressibility indicates deformations produced in soils (C.L.).
Shear strength of soil is its ability to resist shear stress. It determines
1. Stability of slope
2. Bearing capacity of soil
3. Earth pressure on retaining stress.

Soil types

Clay

Types

two types of clay for consideration in British conditions:
1. Normally consolidated
2. Over-consolidated

Normally consolidated clay exists under effective stresses that have never been exceeded

over-consolidated clay currently exists under effective stresses lower than those experienced in the past

Consolidation

Consolidation history has a major impact on the behaviour of the material as fill because it controls both shear strength and water content

Glacial

Glacial clays are over-consolidated as they were deposited below ice sheets some 30 m thick

Swelling in over-consolidated clay

A problem with over-consolidated clay is that low (sometimes negative) pore pressures exists, particularly when excavated from depth, due to a change of stress state.
Normal earthworks sequencing takes cut materials from base of a cutting and place them on top of embankments, increasing the likelihood of swelling over the long term.
Over-consolidated clay may, therefore, be difficult to work in such circumstances.

Overconsolidated Soil is tightly packed and has low pore/void pressure. When you dig it up + use it as embankment fill, the pore/void pressure restabilises + the voids open. This may cause swelling (Volume ↑)

Characteristics of coarse (granular)

Definition

Soil that exhibit non-plastic behaviour during the re-moulding of a moistened sample

BS EN ISO 14688-1

Soil description

coarse soils typically contain less than 35% fines (,0.063 mm)

Earthworks fill classification

defines material with less than 15% fines as 'granular fill'

SHW (HA, 1998, 2013)

at fines contents greater than about 15%, the soil is often no longer free draining

Correlation

no direct correlation between the descriptive 'coarse soils' provided in BS EN ISO 14688-1 and the fill classificatory 'granular fill' in SHW (HA, 1998, 2013).

Origin

tend to have been derived from a water-borne origin (river, marine or glacial melt-water) or wind-blown origin

Coarse (granular) soils are normally free draining and easier to handle, in an earthworks context, than fine (cohesive) soils

relatively trouble free when employed as fill

Issues

Collapse settlement

- can occur with some weak rocks as well as with cohesive fills
- unlikely to occur within embankments as the equilibrium groundwater level is in the natural ground below the embankment toe. Collapse settlement in earthworks fill, although uncommon, is typically due to rain water infiltration.

Frost-heave

granular fill with low silt content (i.e mostly large graded without much small grading - i.e mostly large particles) are non suspectible to frost-heave.

GH Note: Likely because the large gaps provide space for water to expand into when it freezes. For this reason, cohesive materials are more frost-heave suspectible than granular material for the same given water content.

Grading

Estimate of particle size distribution made by attaching qualifiers 'well graded', 'uniformly graded' and 'gap graded' to their soil descriptions.

Well graded = good distribution of grades.
Uniformly graded = mostly contains one (or more) grades.
Gap graded = lacks one (or more) certain grades.

- Well-graded granular fill generally has the best engineering properties.
Abundant particle contacts reduce inter-particle stresses and associated breakage; and the smaller particles help increase density by filling void spaces.
- Those with rounded particle shapes are harder to compact than those with angular particle shapes
- Care should be taken when mixing fills.

Although mixing a finer grained granular material into a coarser one might give better compaction and density, it could later experience segregation, and therefore a loss in relative density and strength, if used in a running surface i.e. unpaved roads and temporary haul roads.

Also, adding coarse material to a fine grained material to 'produce' a better material should be avoided, as this usually results in gap-graded material with no additional strength benefit to the parent material

Mercia Mudstone

- red-brown mudstones with subordinate siltstones and sandstones
- Only highly weathered Mercia Mudstone has soil-like consistency and engineering properties
- low plasticity index
- Stockpiling of unsealed or un-compacted mudstone can also become unacceptable as engineering fill if left exposed to the elements
- As Mercia Mudstone is predominantly silty it is generally susceptible to frost action

industrial fill

use of waste industrial and construction products (i.e demolition waste) for engineering fill is a growing practice.

Legislation has made in attractive in the UK for financial and sustainability reasons.

Unfortunately, industrial materials may themselves be unsuitable by virtue of their chemical or physical properties, and so what appears to be an excellent environmental solution may bring other engineering problems

Flow chart for determining suitability of waste materials for use as engineered fill (BS 6543)

- Demolition waste is typically used to construct temporary haul roads and platforms for cranes and piling plant
  - materials that comply with SHW are now commonly left in place as part of the permanent works, e.g. LTPs for piling works
- crushed concrete material has been generated as a granular fill material

landfill tax to discourage the disposal of waste to landfill
- £80.00 per tonne for active waste and £2.50 per tonne for inactive waste (generally concrete, brick, glass and soil)

aggregate tax may apply to fill imported from borrow pits

Summary

These factors can make the use of recycled materials more attractive

Earthworks specifications

Contract that describes the design requirements of the project

developed as a collaboration between the client, designer and contractor to optimise the use of excavated materials for use as engineering fill and define the properties of imported material

3 main types of compaction specifications for construction of embankments or engineering fill below foundations:

1. Method specification

- A method specification defines how compaction should be conducted in terms of the types of compaction plant, the number of passes and the compacted layer thickness
- Site testing is required for site quality assurance and control to ensure that the prescribed compaction method is being correctly applied

2. End-product specification

- the designer defines a ***minimum density*** for the engineered embankment fill material
- material acceptability usually determined in similar manner to that for a method specification.

Compaction to achieve the required density with respect to layer thickness, plant type and weight and number of passes is decided by the contractor, but may be based on a method specification and verified by site tests.

3. Performance specification

- Compaction is considered not only during construction but also throughout serviceability. I.e. no more than 25mm settlement 5 years after construction
- Typically considered onerous from contractual viewpoint as places the risk of all future events on the contractor. Also usually very difficult to monitor in practice

Hybrid specification

also numerous hybrid forms

Most popular is to use SHW as the basis, with some small changes e.g. modifying plant type, number of passes and layer thicknesses.

The changes usually based on local knowledge of fill type and experience with particular equipment. However, introduction of changes may complicate the issue of liability under the contract.

SERIES 600 EARTHWORKS

General Classification

- acceptable material
- unacceptable material Class U1A
  - Materials comprising:
    • peat, materials from swamps, marshes and bogs
    • logs, stumps and perishable material
    • materials in a frozen condition
    • clay with very high plasticity
    • material susceptible to spontaneous combustion
- unacceptable material Class U1B
  - contaminated materials not hazardous or radioactive
- unacceptable material Class U2
  - hazardous and radioactive waste

Reuse

unacceptable material (other than Class U2) shall be processed by ***mechanical, chemical or other means*** to make the material acceptable for use in the permanent works

Definitions

Formation

Top surface of capping. Where no capping is required formation shall be the top surface of earthworks at the underside of sub-base

Sub-formation

Top surface of earthworks at the underside of capping

Stabilisation

Treating material by spreading cement or lime (or both) on it, pulverising and mixing it, and then compacting it

As dug

Material that has been excavated, transported and placed without any processing, cleaning or sorting

General Requirements

- Contractor is responsible for maintaining the nature of the acceptable material so that it is still acceptable after being placed and compacted
- Can only haul material to an embankment when there is sufficient spreading and compaction plant ready to use
- No surplus material which can be used within the works can be removed from the site/works by the contractor. If he does, he needs to replace the material to ensure the same net balance is achieved had he not removed the material. Otherwise, it is theoretically like he is stealing from the project for his own personal gain.
- Any surplus cut material (other than topsoil) not needed in the permanent works needs to be disposed of. It can't just be left on site at the end of the project.
- The contractor must excavate material in a way that ensures no mixing/ contamination between acceptable and unacceptable materials, or between classes occur (assuming the classes are to be placed non-homogeneously).
  - How would a contractor do this in reality though?

Topsoil

- Existing topsoil should always be stripped as ***turf*** before placing embankments/cuttings. It should only be left in place in locations it isn't going to be constructed over.
- wherever practicable, should:
  - be used immediately after its stripping,
  - not stockpiled over 2m high
  - not stockpiled for > 2 years
  - not be compacted/ surcharged, including unnecessarily before it's stripped e.g. during site prep
  - not be handled multiple times if avoidable

  This is because all of the above degrade the topsoil for agricultural use.
- If short of Class 5A (natural topsoil) for recoiling purposes, Class 5B material can be externally imported as a replacement

Forming of Cuttings and Cutting Slopes

Cuttings can be halted at any stage as long as at least 300mm of material as a weather protection is left in place above the formation or sub-formation

- Wouldn't cutting already be cut to the required depth if you've reached formation?

Watercourses

Redundant watercourses should be drained and cleared, and material outside the watercourse profile excavated and treated as ***unacceptable material***. It should then be filled with general fill, compacted and topsoiled or seeded over. I.e. you can't just leave redundant watercourses in place

Construction of Fills

Starter layer (Class 6) shall be deposited as the first layer of fill above existing ground level or any ground improvement

Plant movement over SL shall be restricted to avoid damage