GEM Engineering, Inc.

GEOTECHNICAL ENVIRONMENTAL & MATERIALS SERVICES

Controlled Fill

Fill is any material such as clay or gravel (or unconventional materials such as crushed clay brick or ash) used to build up the level of the land. Fill that is properly controlled during placement can support most moderately loaded structures. In many cases, fill that is properly controlled actually can exhibit properties that are superior to and more predictable than those of native soils.

Elements that must be controlled to construct a fill that achieves design criteria include:

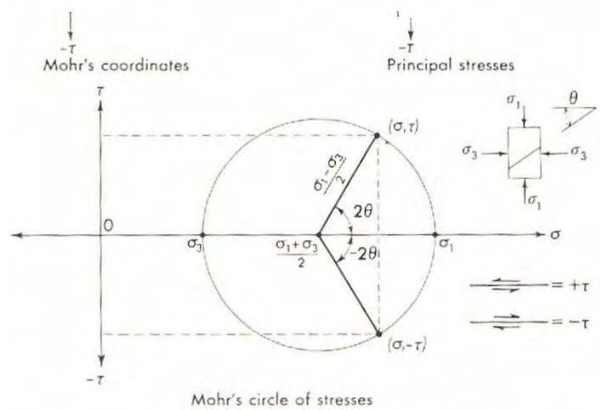
- Subgrade preparation (e.g. stripping topsoil and soft inorganic soil)
- Fill material (e.g. non-deleterious materials capable of achieving required properties)
- Placement/compaction techniques (e.g. layer thickness is within prescribed limits)

Control of these elements must be fully documented to confirm substantial compliance with the project specifications. Documentation includes test results and records of construction observations.

Design

Controlled fill is designed and specified like other construction materials. The first step is to determine the properties that the fill must provide. Design properties may include:

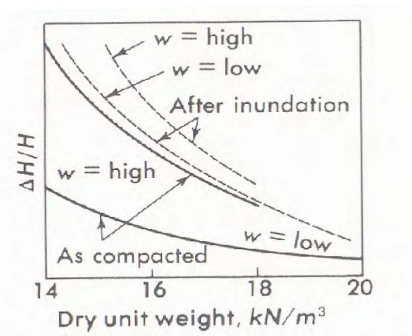
- Undrained Shear Strength (e.g. foundation support)
- Drained or Effective Shear Strength (e.g. stable dam embankment)
- Hydraulic Conductivity or Permeability (e.g. clay landfill liner)
- California Bearing Ratio [CBR] (e.g. pavement subgrade)
- Subgrade modulus (e.g. industrial floor subgrade)
- Density (e.g. reduced pressure against a basement wall)



Mohr coordinates and Mohr's circle of stresses.

Most of these properties can be correlated to the material type (e.g. clay or gravel), moisture content and compacted density. Accordingly, most fill specifications include requirements for these properties.

When fill embankments are being designed, the embankment slopes will be determined based on a stability analysis. Other factors also may come into play. For example, if the underlying soils are saturated, the rate of fill placement may have to be controlled and the subgrade hydrostatic pressure monitored, in order to preclude loss of strength caused by reductions in effective stress that could lead to failures. Consolidation may be a design factor, particularly for deep fills over compressible soils.



b. Compressibility for a constant σ'_0 and $\Delta\sigma$, compacted

Subsurface Conditions

Every structure, including a controlled fill embankment, must have a good foundation. Accordingly, a subsurface exploration often is conducted to identify subsurface conditions that could impact the fill. Important subsurface conditions that generally are explored include:

- Topsoil depths
- Compressible soil deposits
- Sinkholes
- Groundwater
- Existing (possibly uncontrolled) fill

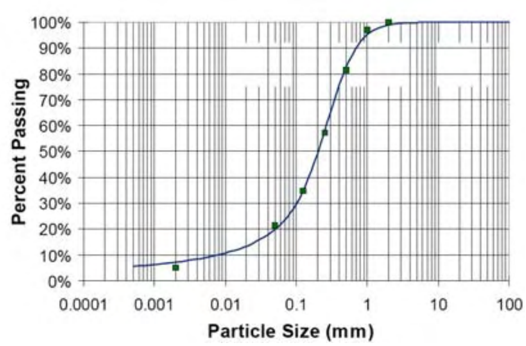
Subgrade Preparation

Prior to placing fill, the subgrade must be properly prepared such that unsuitable existing materials are removed and that the subgrade is strong enough to allow the new fill to be properly compacted. Important elements of a properly prepared subgrade include:

- Clearing and grubbing of vegetation
- Stripping of topsoil and root zone
- Removal or stabilization of soft surface soil
- Proper treatment of existing fill
- Identification and stabilization of sinkholes

Retaining a geotechnical engineer to evaluate the subgrade and if necessary to provide remedial recommendations for problem areas is the best way to achieve a good subgrade. The evaluation typically would include observing the appearance of the subgrade and degree of deflection as a suitably loaded vehicle or piece of construction equipment is driven over the surface (proofrolling).

Fill Materials



Suitable fill materials are described in the project specifications. To avoid problems, it is important that the fill specifications are consistent with the recommendations provided by the geotechnical engineer in the geotechnical exploration report for the project. Suitable fill materials generally are specified based on a number of properties including:

- Particle size
- Plasticity
- Maximum organic content
- Minimum dry density

The majority of fill materials used in the central US fall into three general categories:

- Native fine-grained soils (silts and clays)
- Native coarse-grained soils (sands and gravels)
- Aggregates (crushed stone) either sieved to a specified gradation or unsieved (e.g. “shot rock)

Many other materials are used as fill for a variety of special applications. Examples of these materials include:

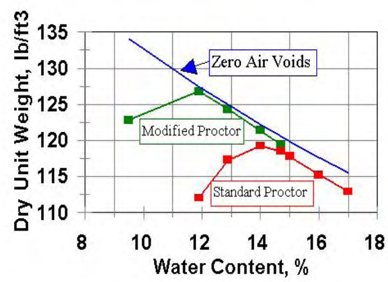
- Controlled low strength material (CLSM or “flowable fill”)
- Recycled concrete & bituminous pavement (asphalt)
- Fly ash / bottom ash
- Slag
- Lime or cement stabilized soil
- Expanded shale (low density fill)

Placement/Compaction Techniques

Several factors must be monitored and controlled when the fill is placed and compacted in order to achieve the necessary properties. These factors include:

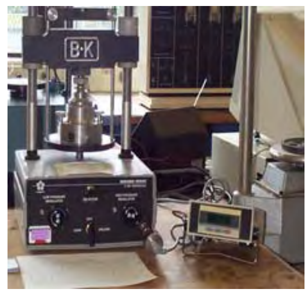
- Slope of subgrade surface - Generally must be near horizontal to optimize the effectiveness of compaction energy and to reduce the potential for a slippage plane between lifts or at the base of the fill. Horizontal steps or benches commonly are excavated to allow for proper placement of fill on slopes.
- Lift thickness – Must be thin enough such that the compaction effort densifies the entire layer.
- Compaction equipment – Must have proper configuration (e.g. weight, roller configuration, speed, vibratory capability) to effectively density the fill material.
- Moisture content - Proper compaction of clays and silts only can take place if the moisture content is maintained within a fairly narrow range. Wetting or drying generally is required if the moisture content is outside this range. Compaction of sands is less sensitive to moisture. Compaction of clean gravel is relatively insensitive to moisture.
- Number of passes - The fill must be properly compacted achieve the target density. Compaction energy is imparted to the fill each time the compactor passes over a given area. For a given set of conditions, some minimum number of passes must be made to achieve the required level of compaction.

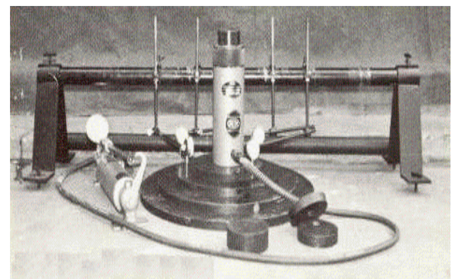
Monitoring, Testing and Documentation



Monitoring of fill compaction and testing of compacted fill properties provided confirmation that the specified properties are achieved. These steps are necessary even if the earthwork contractor is highly skilled due to complex and often subtle variations in the compaction process and the fill materials. Commonly conducted tests include:

- Proctor (standard or modified)
- In-situ density
- Moisture content
- Soil Classification





Other less frequently used tests include:

- Field CBR
- Modulus of Subgrade Reaction
- Shear Strength
- Unconfined Compressive Strength
- Permeability

How does controlled fill improve the project?

Controlled fill is a means in which to alter the site ground surface to meet the project needs to achieve the desired final grades and subgrade properties. Controlled fill can be used to raise or level the site so the project can be constructed at a reasonable cost. Controlled fill can be used to replace less than desirable material encountered within the site subgrade. Controlled fill can provide a more predictable bearing material for the project. Unsuitable conditions can be improved by implementing special methods such as chemical stabilization or placement of geosynthetics on difficult sites. These methods can allow for less expensive foundation and slab-on-grade systems to be utilized. The geotechnical engineer can provide specific solutions for each individual project to improve the site conditions with fill placement methods. Designing and controlling fill is an important operation in geotechnical engineering. No two filled sites are the same and varying conditions over a filled site make careful subsurface exploration essential. Fill that is properly controlled can provide suitable support for most structures on all but the most exceptional sites.