Ground Improvement –
A Discussion on Dynamic Compaction

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Presentation Outline

• Provide a basic understanding of the principles involved in the design and implementation of a dynamic compaction program.
• Discuss construction-phase issues that can arise.
• Illustrate some case histories and highlight the various soil types that are conducive to improvement by dynamic compaction.
Dynamic Compaction

The Operator

The Crane

Some Dudes Watching the Weight Drop

The Pounder
Typical Dynamic Compaction Program

- Consists of the repeated dropping of a 5 to 20 ton weight from heights varying from 60 to 100 feet on a grid pattern.
- Most applicable to granular fill materials and sandy deposits.
- Depth of improvement is generally limited to about 25 to 30 feet or less.
- Shallow groundwater table not ideal for schedule, as energy is lost at the soil/water interface and pore pressures build up, requiring more time to complete the program.
- Generates very high vibration levels, not ideal for sites in close proximity to sensitive existing structures (less than 50 feet or so).
Advantages to DC

- Allows conventional spread footing foundations
- Replaces expensive deep pile foundations
- Helps mitigate deep foundation costs in liquefiable areas
- Highly cost-effective when compared to other forms of ground improvement.
- Reduces settlement
- Increases bearing capacity
- Eliminates risk of hazardous waste exposure resulting from conventional undercut and replace (stays buried)
- Self-compensating – Softer areas are immediately apparent: and additional energy can be applied
Soils Conducive to Dynamic Compaction Improvement

- Loose Sands
- Uncontrolled Fills
- Debris Fills
- Mine Spoils
- Sanitary Landfills
- Old Sand / Clay Pits
- Boulder Fills
- Liquefiable Soils
- Sinkhole / Mines
- Collapsible Soils
- Landfill Liner Preparation
**Important Geotechnical Design Parameters**

<table>
<thead>
<tr>
<th>Sieve Analysis</th>
<th>Hydrometer Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>size of opening in inches</td>
<td>number of mesh/in. US std</td>
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</table>

| Zone 1 | pervious soils plasticity index (Pl) = 0 |
| Zone 2 | semi-pervious 0<Pl<8 |
| Zone 3 | impervious Pl>8 |

<table>
<thead>
<tr>
<th>Percent Retained by Weight</th>
<th>Percent Finer by Weight</th>
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</thead>
<tbody>
<tr>
<td>GRAIN SIZE IN MILLIMETERS</td>
<td>GRAIN SIZE IN MILLIMETERS</td>
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</tbody>
</table>

- **Zone 1**: Pervious soils with plasticity index (Pl) = 0
- **Zone 2**: Semi-pervious soils, 0 < Pl < 8
- **Zone 3**: Impervious soils, Pl > 8

**Grouping of Soils for Dynamic Compaction**

- Cobbles
- Gravel
- Coarse sand
- Fine sand
- Medium sand
- Fine
- Silt or clay
- Fines

Lukas (1986)
Depth of Improvement

The Dynamic Compaction Process
(Lukas 1995)

\[ D = n \sqrt{WH} \]

\[ 0.3 < n < 0.6 \]
The Dynamic Compaction Principal
Governing Design Formulas

Depth of Influence:

\[ D = n \times \sqrt{W \times H} \]

\( n \) - an empirical value based on soil type and varies from 0.35 to 0.6

\( W \) - weight in Mg

\( H \) - drop height in meters
Governing Design Formulas

Applied Energy (AE):

\[ AE = \frac{(N \times W \times H \times P)}{(\text{grid spacing})^2} \]

N is the number of drops
W is the weight in Mg
H is the drop height in meters
P is the number of passes

Note: What’s not in here is the contact pressure of the tamper.
Recommended Applied Energy

Recommended Energy Levels based on soil type are as follows:

Pervious Coarse-Grained Soils (Zone 1) – 200 to 250 kJ/m$^3$
Semi-Pervious Soils (Zone 2 and 3) – 250 to 350 kJ/m$^3$
Landfill Material – 600 to 1,100 kJ/m$^3$
Pounder Contact Pressure

• Although not accounted for in design formulas, contact pressure of the pounder is a vital component to successful program.

• Example:
  – 16-ton weight, 7-foot round, 889 psf contact pressure.
  – 15.3-ton weight, 5-foot octagon, 1,417 psf contact pressure

• Higher pressure better for punching; lower pressure better for uniformly lowering a site.
Design Considerations

- Historic Site Usage
- Subsurface Conditions
- Settlement
  - Long term and short term
- Schedule
Design Considerations

- Historic site usage
  - Understanding the prior use of a site can easily rule out the use of a specific type of ground improvement.
  - Specifically, old foundations, structural elements, etc. can prohibit the ability to fully implement the recommended program.
  - Environmental concerns can also be of significance when it comes to on-site soil handling concerns.
Design Considerations

• Subsurface Conditions
  – Highly plastic soils likely not the best application for DC.
  – Shallow groundwater may require more phases to the program to allow for dissipation of pore pressures.
  – Variable fill materials may require granular material to stabilize.
Design Considerations

• Settlement
  – Granular soils will generally demonstrate post-construction settlement during building construction.
  – Perhaps most importantly, it should be understood that ground improvement generally does not eliminate settlement. It minimizes it to tolerable levels. The anticipated settlements need to be discussed early between the geotechnical and structural engineers and accounted for in the design.
Design Considerations

• Schedule
  – Dynamic compaction can generally be implemented at a pace of 5,000 to 10,000 square feet per day, per rig, making it a relatively schedule-friendly form of ground improvement.
  – Winter weather can impact the schedule in the same way that it can a traditional earthwork program.
  – Tighter sites require more surgical approach, meaning a longer schedule.
Real-Time Quality Control

- On-site inspection
- Crater depths (mapping)
- Surface elevation monitoring (settlement vs. heave)
- Decrease in depth of weight penetration with successive drops
- Pore pressures
Dynamic Compaction Drop Plan
Post-Improvement Acceptance Testing

- Large-Scale Load Test (where CPT & SPT are unreliable i.e. construction rubble and cobbles)
- Standard Penetration Test (SPT)
- Cone Penetrometer Test (CPT)
- Pressuremeter Test (PMT)
- Dilatometer Test (DMT)
- Shear-Wave Velocity Profiling

KEY IS TIME!!
Vibrations
Dynamic Compaction Vibrations

![Scaled Energy Factor vs. Particle Velocity graph]

- Very Disturbing
- Disturbing
- Strongly Perceptible
- Distinctly Perceptible
- Slightly Perceptible

Scaled Energy Factor (\(\sqrt{\text{Energy-ft.pounds}}\) / Distance-feet)

Lukas (1986)
Dynamic Compaction Vibrations

16-ton Weight Attenuation Curve

See report text for explanation.

Norfleet Consultants

Delta Coves, Bethel Island, CA

16 ton - DDC Attenuation Curve - PPV vs. Distance

PROJ NO: 061729 DATE: 8/10/2006 FIGURE: 7

Densification, Inc.
Vibration Reduction Measures

Isolation

Trench
Vibration Reduction Effectiveness

![Vibration Monitoring Results Graph](image-url)
Project Examples
King of Prussia, PA
Searching for Karst Sinkholes
Saratoga Springs, NY
Loose Sands
Jersey City, NJ
Fill Site
Fort Lewis, WA
Fluvial Outwash
Lake Shore Drive
Chicago, IL
Ash Fill from Coal Tunnels beneath the City
Yoloten, Mary, Turkmenistan
Leveled Dune Sands
Prudential Center
Newark, NJ
Fill Material
Job Where
Geotechnical
Field Engineer
Gave our
Operator a
Hard Time
Questions??

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