Construction and Geotechnical Issues

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Introduction

- Ground conditions for port development
- Ground conditions for airport development
- Loading conditions
- Geotechnical issues
- Construction issues

Disclaimer – all opinions are the presenter’s and not necessarily those of AECOM
Ground Conditions - Port Development
Port areas are typically created by land reclamation
• by deposition of dredged materials
• by dumping of fill
• treatment of the placed material to provide sufficient strength and stiffness,

Underlying soils frequently contain soft normally consolidated clays

Photo courtesy Coffey Geotechnics
**Issues**

- underlying soft soils will have variable properties
- underlying soft soils likely to have variable thickness (paleo-channels?)
- long term consolidation and creep of soft soils
- support of edge of reclamation fill over soft soils (strength gain?)
- densification and settlement of reclamation materials

**Time for treatment**
- Total settlement
- Differential settlement
- Stability
Ground Conditions - Airports
Issues

• some airports developed under exactly the same conditions as sea ports
• airports also developed on land – usually relatively straightforward geotechnically except for:
  – reactive clays
  – high water tables
Loading Conditions
Load conditions for subgrade design different to those for pavement design:

- Localised loads from container handling equipment or aircraft wheels are distributed by the pavement and generally do not affect long term settlements.
- Ports may have high long term distributed loads due to container block stacking.
  - Eg: For average load of 15t in 20ft containers,
    - 3 high = 30kPa approx
    - 5 high = 50kPa approx
  - Could be much higher for special purpose goods with average higher loads.
  - Loading only over part of pavement area ➔ possible differential settlement at edges.

Sometimes operational conditions are not known at the time of development.
Geotechnical Issues
Geotechnical design considerations

Geotechnical design has to consider a range of issues, including:

• geotechnical design criteria
• constructability and selection of treatment options for reclaimed materials and/or soft soils
• complexity of the design process
• source and consistency of reclamation materials
• upper subgrade layers
• long term uniformity of pavement support conditions
• design of transitions and edges
Geotechnical design criteria

Geotechnical design are often difficult to establish, because:

- the developer (e.g., a port owner) is often different to the final operator(s) and so operational tolerances hard to define, and lower tolerances means higher cost
- the developer typically wants low cost, fast solutions with little risk – often incompatible objectives
- pavement performance requirements are often difficult to relate to geotechnical criteria (for example, what rotational settlement can different types of pavements “withstand”)
Treatment Options for Soft and Reclaimed Soils

There are a multiplicity of treatment options for soft soils and loose reclaimed materials, including:

• preloading and surcharging soft soils in conjunction with wick drains
  – requires granular layer for support of wick installation equipment and for wick drainage
  – edge stability for high surcharge critical and possibly limiting rate of loading
  – volume of materials required for preload and surcharging may be prohibitive for large areas (eg 20ha, 5m high fill ➔ 1,000,000m³)

• vacuum consolidation of soft soils with wick drains
  – can impose effective vertical stress up to 80kPa
  – site has to be covered with airtight membrane – may require cut-off walls to the top of the clay layer being consolidated, possibly through weak reclaimed materials
  – less stability concerns than surcharging, no fill required
Treatment Options (2)

- quality control of soft soil consolidation by monitoring of settlement and pore water pressure
- deep soil mixing soft soil to form lime/cement columns
  - up to 30m depth possible
  - columns can form interlocking grids or blocks at edges of surcharge areas for stability
  - may need high strength geotextile to distribute fill loads to columns
  - difficult to establish consistency of column cross-section and strength
- vibro-compaction of loose granular (non-cohesive) soils
  - uses a vibrating probe to up to rearrange and densify the particles, with granular backfill placed into holes formed by the densification
  - 40m depth possible
  - quality control typically by cone penetration testing at mid-point between compaction probe locations
Treatment Options (3)

- **vibro-compaction / stone columns in non-granular soils**
  - similar technology to vibro-compaction but forms compacted rockfill columns to reinforce the soft soil and accelerate drainage

- **dynamic compaction of loose soils**
  - uses a heavy mass (10t – 25t) falling 10m – 20m, with repeated drops at each location
  - quality control typically by cone penetration testing at mid-point between compaction probe locations
  - variation is “dynamic replacement” where stone or granular fill is driven into the ground to form large diameter stone columns to reinforce upper levels of the soil profile and provide improved drainage
  - may be used in conjunction with wick drains

- **impact rolling of loose soils**
  - uses straight-sided rollers to impact the surface, effective up to 5m
Design Issues

Design of soft soil treatments is complex and has to take into account:

- creep behaviour of clays (significant factor in post-construction settlement)
- variability of settlements and rate of settlement due to intrinsic variation in the soil properties and layer thicknesses
- time-development of strength with changes in effective stress
- requirement for adequate investigation, field testing, high quality sampling and laboratory testing
- trade-off between investigation costs and reliability of the design
- design of instrumentation for monitoring the construction process, and adjustment of the design during construction if indicated by analysis of the monitoring data
Complexity of Design (2)

Other design issues:

• controlling differential settlements, particularly at junctions with “rigid” (e.g. piled) pavements
• transitions and edges
• long term performance when creep is a significant factor
• thickness and materials forming the final subgrade
• provision of adequate working platforms to support construction equipment
Construction Issues
Construction Issues

Topics:
- roller compaction
- issues for cemented layers
- quality issues
Roller compaction

Factors to take into account in roller compaction:

• requirements for successful compaction
  – suitable moisture content in soils
  – stiff supporting layer
  – roller type, size and number of passes matched to soil type and layer thickness
  – lateral confinement
  – vertical confinement for vibrating rollers on sand

• matching density levels with function
  – layers close to top of subgrade need high density to provide strength for pavement support
  – layers deeper in the profile require less strength and compaction levels should match settlement requirements

• matching roller vibration levels to soil strength
Roller compaction (2)

- defining a “lot” for acceptance purposes
  - areas of work that are essentially **homogeneous** with respect to the state of the underlying materials, material origin and properties, appearance, moisture condition, compaction technique and response to compaction
  - best way to check this on large areas is to use roller technology such as recording of GPS-based coverage data and roller response data
  - homogeneity is the key that test data has meaning

- compaction acceptance criteria options
  - statistical “characteristic” density; preferred because a homogeneous, low variability product is required
  - all test results must pass; can be misleading if the number of tests is not linked to the variability of the results
  - limited proportion of test results can fail; see above
  - mean of results must pass; very poor because more than half of the lot can be less than the specified level
Issues for cemented layers

Some issues that don’t always get the attention they deserve

• to achieve uniform homogeneous material on the ground needs:
  – adequate mixing time
  – specific-purpose mixing machinery in good condition
  – spreading procedures that avoid segregation
  – uniform compaction in adequate time

• adequate bonding between sub-layers
  – the design is almost certain to assume that the whole layer is homogeneous, so need to ensure that assumption is realised

• curing
  – this includes the exposed surfaces of sub-layers as well as the final surface
Quality control

Quality control for earthworks requires more than the lot test data
- a construction methodology focussing on reducing the risks of non-conformance
- a checking process for lot homogeneity
- full time presence of the designer’s representative is recommended, to confirm that design assumptions and requirements are being achieved
- immediate review of the lot test data, particularly for indications of increased variability, and implementation of corrective action
- up-to-date process control charts