Challenges for the Compaction and Proving of Granular Fills and Layers in Australian Airport Pavements

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History of Airport Pavements

• Prior to WWII, Australian aerodromes comprises of natural soil and then lightly gravelled runways in the 1930s

• Airport pavement design and construction developed after WWII as aircraft began evolving from light and robust machines to heavier aircraft

• US Army Corps of Engineers subsequently started investigating pavement design and construction methods
Modern Airport Pavements

- Australian airport pavements typically designed with 50-60 mm asphalt surfacing or spray seals due to adopting high quality FCR.
- Other countries such as the USA typically require a minimum of 125mm asphalt to account for lower quality crushed rock.
- Adopting more FCR is based on maximising the use of low-cost natural soils and gravels, which originated during WWII from a lack of availability of manpower and materials.
- Australian airport pavement construction subsequently relies on proficient compaction and proof rolling techniques.
Granular Pavement Layers

- Granular material makes up majority of pavement structure
- Granular pavement layers generally include unbound base and subbase layers – typically referred to as Fine Crushed Rock (FCR) and Natural Gravel
- In some European countries and places like the US full depth asphalt or concrete pavements are used with granular material restricted to working platforms
Deep Sand Fills

• Fill material is placed between the natural subgrade and overlying formal pavement structure
• Hydraulically or mechanically placed dredged sand over low strength marine clays common where airports built on reclaimed land
  • This occurs at airports such as Sydney, Brisbane and Cairns
• Depth can be significant, up to 5 to 10m
• Most economical to place in thick layers up to 1.5m deep
• Sand fill usually placed in a single, thick layer where compaction and density testing at depth is expensive
• Reliance on proving whole fill thickness rather than layers
Compaction & Proof Rolling

• Compaction increases the density of material by applying mechanical energy to reduce air voids
  • Load bearing capacity, settlement, swelling & contraction potential, frost
• Proof rolling is the process of applying a roller load to a layer to induce stresses throughout the layer to exceed stresses induced by aircraft during service
• For granular pavements stress is higher near the surface and therefore larger, heavier rollers with high tyre pressures are required
• For granular fills, the required proving stress at the bottom of the pavement is lower, but layers are thicker so proving stress must penetrate further
Moisture

• Must prove layers in their most compactable condition, which for Select Fill and granular rock is OMC

• Single sized sands are most compactable either fully dry or completely saturated

• Not practical to completely dry sand fills and therefore they are compacted and proof rolled in a saturated condition

Flooded sand compaction (source: White, G (2017))
Rollers in Construction

- Department of Housing and Construction started designing and building proof rolling equipment from the 1950s
- 200 t Supercompactors (up to 1.0 MPa) imported from the USA to be used for deep sand fill compaction
- 50 t Marco Rollers built locally (and some procured from the USA as well) used to compact FCR
- One Marco roller tyre pressure increased to 1.65 MPa – Boeing 727
What Happened to the Rollers

- Trials at Sydney Airport determined that vibratory rollers probably could achieve densities at depth similar to the Supercompactor.
- Size and logistics of the Supercompactor resulted in the use of vibratory rollers instead.
- Marco rollers previously overinflated to 1,400 kPa, tyre manufacturers removed this and now inflate to 1,000 kPa only.
- Smaller and dynamic rollers used based on an assumption of equivalent performance to older, heavier rollers.
Compaction & Proving Gap

• Proving airport pavement granular fills and pavement layers requires significantly larger rollers than those used in road construction.

• Now there’s a gap in proving the upper granular layers and compaction and proving of deep fills.
Aircraft Developments

- Whilst roller capability has reduced, aircraft loads have increased
- B747-100 in 1966 was a significant increase in load and tyre pressure
Quantifying the Challenge

- Typical new flexible pavement constructed on sand fill over marine clay
- 100mm asphalt, 600mm FCR and 1,500mm sand fill on subgrade CBR 1% adopted for analysis
- Critical design aircraft used to identify most extreme gap for the largest commercial aircraft
Sand Fill Compaction Gap

The graphs illustrate the stress (kPa) versus depth (mm) for different compaction methods:

- **Crushed rock (sub-layered)**
- **Sand fill (not sub-layered)**

Each graph shows stress levels at various depths for different compaction tools:

- A350-900
- B777-300ER
- Macro Roller 1,000 kPa
- Supercompactor
- Macro Roller 1,000 kPa
Base Course Proving Gap

- Marco roller primarily used to prove the granular layers
- Tyre pressure restriction on Marco’s prevents them from inducing stress in the upper granular layer(s) equivalent to the larger aircraft
Potential Solutions for Sand Fill Compaction

- Current design software cannot take into account the additional densification from roller vibration
- Rely on field trials but these are expensive
- Need a theoretical method of analyzing impact of vibrating rollers
- Currently investigating options including energy-based methods, FEM and DEM, and shakedown theory
Potential Solutions for Base Course Proving

• Significant gap in upper granular layers, not concerned with vibratory rollers
• Need to increase the stress induced by the layer being proven
• One option is to fit second-grade aircraft tyres to rollers as these are routinely inflated to 1,700 kPa
• Can also increase asphalt thickness but this is expensive
Conclusion

• Increasing aircraft size and reduced roller capability has resulted in a gap in proving upper granular materials and compacting and proving deep fills

• Gap is minor for deep fills but inability to theoretically compare static and vibrating / impact rollers makes this difficult to quantify

• Gap in granular pavement layers requires higher tyre pressure rollers or thicker asphalt
Thankyou