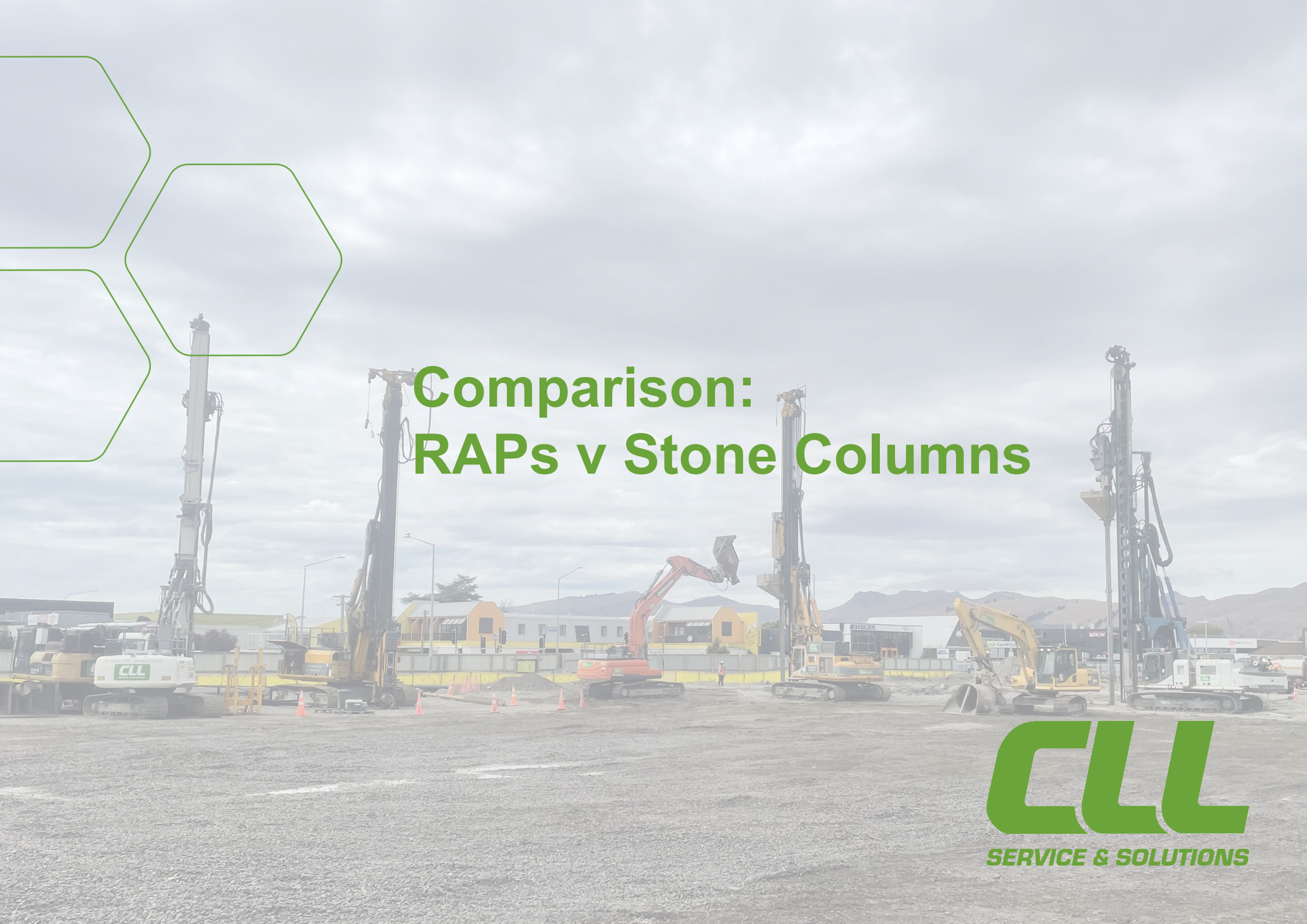

Comparison:
RAPs v Stone Columns

SERVICE & SOLUTIONS

Geotechnical Performance Comparison: Rammed Aggregate Piers vs. Stone Columns

Executive Summary:

This report compares the geotechnical performance of Rammed Aggregate Piers (RAPs) and Stone Columns, two common ground improvement systems. RAPs are particularly effective in a wider range of soil types, including silts and clays, due to their vertical ramming installation method which increases lateral stress and stiffness in the surrounding soil. Stone columns are best suited for sandy soils where their vibratory installation effectively densifies the ground. Both systems help prevent liquefaction during earthquakes by densifying and reinforcing the soil, with RAPs showing promising results in silty sands. RAPs generally exhibit higher vertical stiffness compared to stone columns, leading to better settlement control for supported structures. The choice between the two systems depends on specific site conditions, soil types, loading requirements, and project goals.

1. Best Soil Types:

Soil Type	Rammed Aggregate Piers (RAPs)	Stone Columns
Sands	Suitable.[1] Displacement techniques are ideal for sands below the water table.[2]	Best suited for sandy soils.[3] Effective in loose, cohesionless soils.[4]
Silts	Effective, especially in non-sand conditions (clay, silt, organic-containing, and fill soils).[5] Vertical ramming is important for soils with silt content.[5] Displacement techniques can be used.[2]	Can be used, but a greater concentration of columns is required compared to sandy soils.[3] Can reinforce soft cohesive soils to limit settlement.[4] Horizontal vibration may negatively impact silt.[6]
Silty Sands	Effective.[7]	Can improve loose silty sands.[10]

Soil Type	Rammed Aggregate Piers (RAPs)	Stone Columns
Sandy Silts	Effective.[8]	Can improve loose sandy silts.[10]
Clays	Effective, especially soft/sensitive clays.[5] Vertical ramming increases lateral stresses important for clay content.[5] Drill and fill techniques are ideal for clays.[2] Can reinforce soft cohesive soils.[4]	Can improve clays, especially soft clays with undrained shear strength greater than 400 psf.[10] Bulging can be a concern in very soft clays.[10]
Organic/Fill Soils	Effective.[5]	Suitable for improvement.[12]

2. Liquefaction Prevention:

Soil Type	Rammed Aggregate Piers (RAPs)	Stone Columns
Sands	Help limit liquefaction by displacing and densifying soil, creating a stiff composite mass.[1]	Help limit liquefaction by densifying soil through vibration and introducing stone, creating a stiff composite mass.[3] May increase drainage path.[3]
Silts/Silty Sands/Sandy Silts	Show promise in mitigating liquefaction by increasing density, lateral stress, and shear stiffness.[7] Blast-induced liquefaction testing shows reduced excess pore pressure.[7]	Can mitigate liquefaction by reinforcing loose, cohesionless soils.[4] Installation increases soil density mainly in clean to slightly silty sand.[15]
Clays	Can reinforce soil creating a stiff composite mass.[1]	Can reinforce soil creating a stiff composite mass.[3]

Degree of Ground Improvement Against Liquefaction:

- **RAPs:** Studies show increased resistance to liquefaction in silty sands due to increased earth pressure coefficient and density.[7] Numerical modeling indicates reduced excess pore pressures and shear strains in improved soil profiles.[14]
- **Stone Columns:** Installation can increase penetration resistance (SPT and CPT) significantly in clean to slightly silty sand.[15] Can reduce the cyclic shear stress ratio of reinforced soil due to stiffening.[15]

3. Vertical Stiffness:

Feature	Rammed Aggregate Piers (RAPs)	Stone Columns
Stiffness	Generally, two to nine times stiffer than stone columns.[5] Stiffness modulus can be 10 to 45 times greater than unimproved soils.[18]	Stiffness is lower compared to RAPs.[5]
Settlement Control	Better settlement control due to higher stiffness.[5]	Less effective in settlement control compared to RAPs for the same conditions.[19]
Load Support	Greater capacity and higher bearing pressure.[5] Can handle light to heavily loaded structures.[5]	Effective in increasing load-bearing capacity.[4]

Vertical Stiffness Values:

- **RAPs:** Stiffness modulus (kg) can range from 15 to 50 times the stiffness of the unimproved soil (km).[20] Stiffness values can range from 88 to 190 MN/m³ depending on applied stress.[21]
- **Stone Columns:** Young's modulus (ETX) typically ranges from 20 to 100 MPa under triaxial conditions.[22] Stiffness values can decrease from 20-40 MN/m³ to less than 10 MN/m³ with increasing stress.[21]

4. Effective Friction Angles:

- **RAPs:** Constructed aggregate friction angles greater than 48 degrees, almost 40% greater than stone columns.[5] Can range from 48 to 52 degrees.[25]
- **Stone Columns:** Friction angle of stone column material is a key parameter influencing improvement.[22] Values around 37-40 degrees are mentioned.[26]

5. Summary Table:

Feature	Rammed Aggregate Piers (RAPs)	Stone Columns
Best Soil Types	Wider range, including silts, clays, sands, and fills	Primarily sands, can be used in silts and clays with limitations
Liquefaction Prevention	Effective in various soils, promising in silty sands	Effective in sands, good for drainage
Vertical Stiffness	Higher, leading to better settlement control	Lower compared to RAPs
Effective Friction Angle	Higher (typically > 48°)	Lower (typically around 37-40°)
Installation	Vertical ramming, direct crowd force	Vibratory probe

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