KELLER

ISM 14TH INTERNATIONAL WORKSHOP FOR MICROPILES

KELLER

# Comparison of Micropile Practices

# North America and Australia

THINK SAFE

# Safety Moment:
# progress on safety


# Why Micropiles?

## Restricted Access:

- Headroom Restrictions
- Access Constraints
- Load Capacity - Platforms
- Existing Structures

## Ground Conditions:

- Obstructed Ground – Boulders / Voids / Fill
- Variable Ground – Overburden / Glacial Till / Fill
- Geotechnical Capacity and Performance

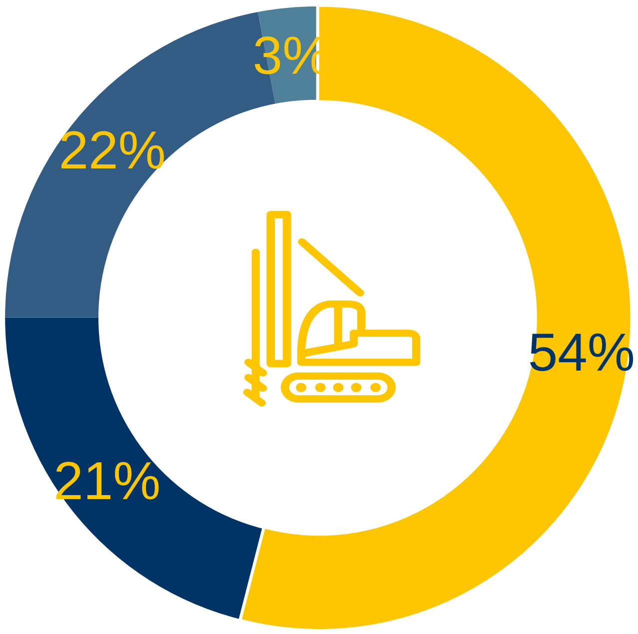
## Economics:

- Rectification Works
- Programme Acceleration
- Demolition VS Access
- Rehabilitation Works
- Retrofit / Seismic Upgrades

# Market Size

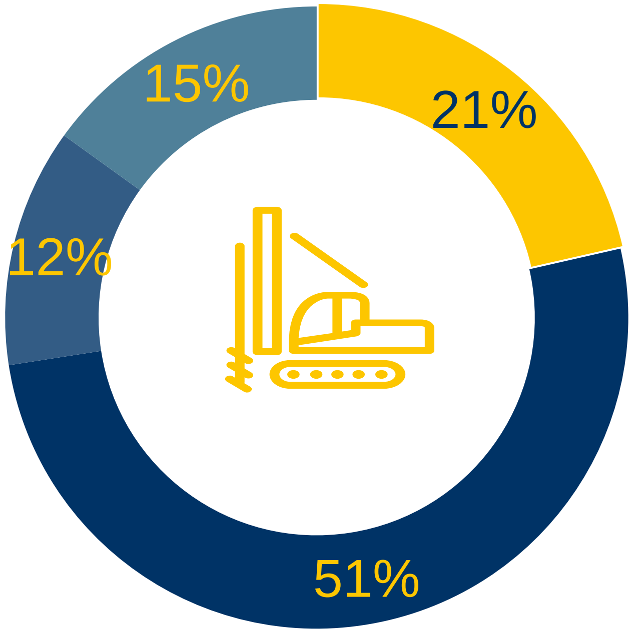
## Where do we Differ??

### Australian Market:




- CFA (Augercast + Displacement)
- Bored (Drilled Shaft)
- Driven (Precast + Franki + Sheets)
- Micropiles

### North American Market:



Case Study

# Restricted Headroom

Star Casino



Central Station

- Ø114-Ø324mm Permanent / Temporary Cased
- Cased Auger System
- Rotary Duplex
- DTH (Super-Jaw)
- Necessarily

- Labour Intensive
- Modified/Specialist Plant
- Stroke & Rod/Casing Change
- Extensive Material Certification – Joint Testing

Sino Iron

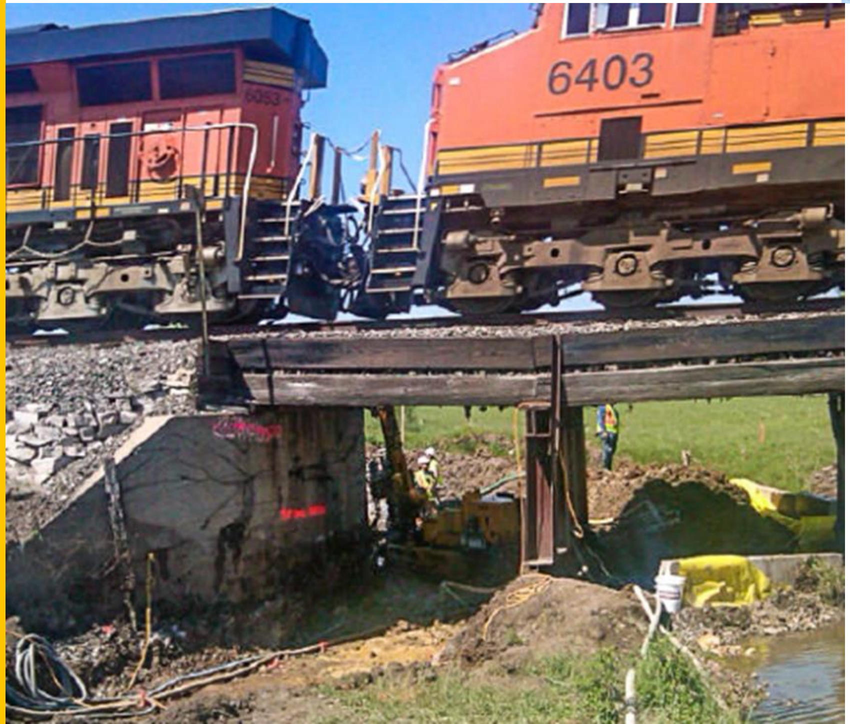
## Case Study

# Restricted Headroom

NSMC – Salem - Rentention

- Labour Intensive
- Modified/Specialist Plant
- Early Works Prior to Major Demolition

NA Rail Bridge




- Contact Lagging to Permanent Cased Soldier Pile Wall
- Foundation Repair/Strengthening

NSMC – Salem - Rentention

Case Study

# Restricted Access

Tropicana Gold Mine

- Rig Drilling Capability
- Required Capacity
- Pre-Fabricated Cages / Single Bar
- 2MN pile

Queens Wharf


- Extent of demolition to enable full size piling rigs
- Excavator Mounted Masts
- Reduced Ground Pressure

Rosewood Rail Bridge

## Case Study

# Restricted Access

- Last Resort When Conventional Rigs Don’t Fit

- Nimble and Versatile

Case Study

# Open Headroom


- Restricted Access
- Ground Pressure Adjacent Excavation Pit
- Limited Working Footprint

Helena Valley - Perth

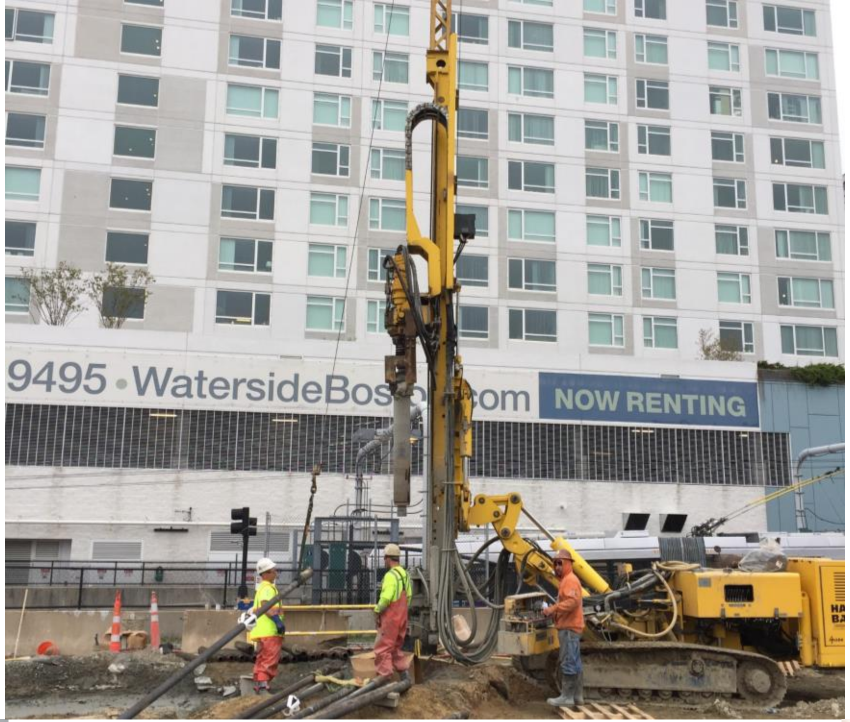
CBD - Sydney

- Conventional Pile Substitute
- Obstructed Ground
- Temporary Works Retention
- Versatile Pile Locations
- Tension Loads

CBD - Sydney

## Case Study

# Open Headroom




- Maximum Stroke for Greater Efficiency
- Larger Rigs – Higher Torque Heads – Larger Diameter = Greater Structural Capacity

NSMC - Salem

SBWTC - Boston

- Glacial Till – SuperJaw DTH

Case Study

# OPT-Sydney

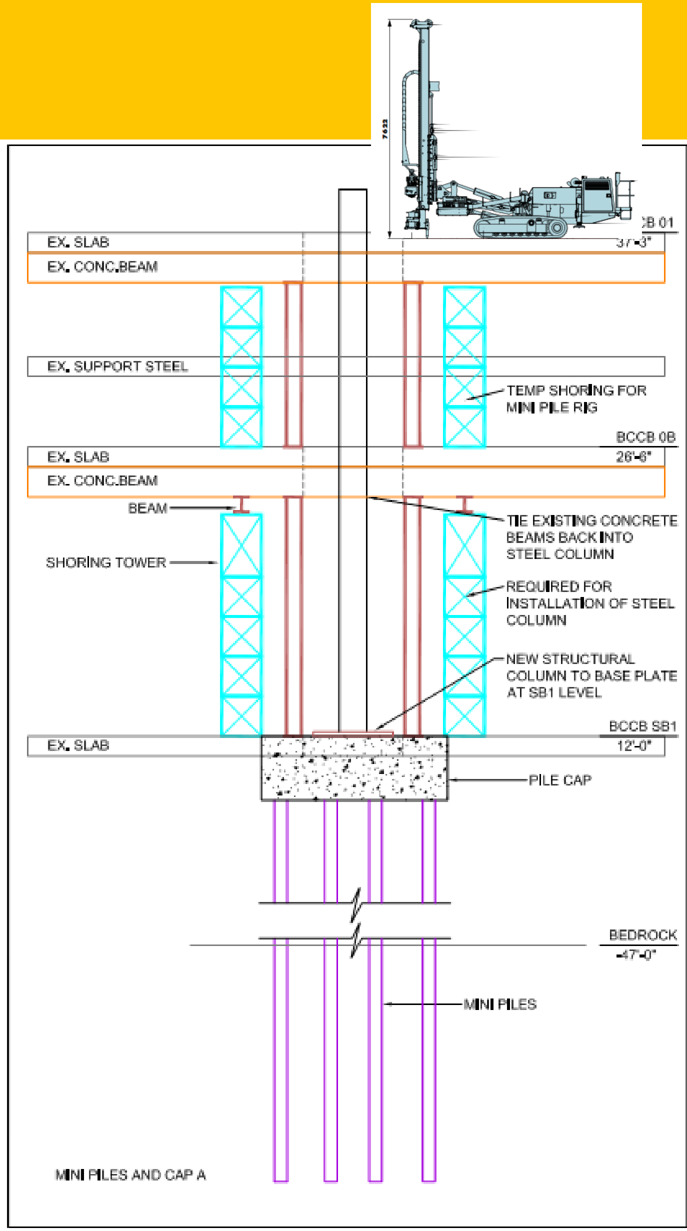
## Platform Requirements

- Tension Anchors installed through driven steel tube pile for new wharf dolphin
- Prefabricated Steel Platform Structure Placed on Wharf Dolphin
- Hutte 609 Dual Rotary Ø219mm casing with Ø190mm bit
- 4no. @ 31m deep within Ø1,200mm steel tube

# Case Study

# BCH-Boston

## Platform Requirements




- 360-ton Micropiles
- 13 $^{3}/_{8}$” Temporary Lining to underside base slab
- 10 $^{3}/_{4}$” x 0.545 cased to rock
- 7” x 0.950 @ 20’ development casing
- #24(120mm) GR. 75 full length reinforcement
- Casagrande M9 Duplex
- 100’ (33m) deep

Case Study

# IMAS-Hobart

Variable Ground Conditions

- Highly Variable Ground Conditions (Boulders)
- Numa Super-Jaw Overburden Drilling System
- 1500+ kN Working Loads
- Ø273/254mm diameter permanent casing
- Cased to rock – bond in socket
- 50MPa grout
- 4no. Tension Tests to AS2159-2009 for verification

Case Study

# SBWTC-MA

Rectification Works

- Obstructed Ground – Tie-backs / Trumpets / Sheets / Concrete
- Rectification of Broken/Undrivable Driven Precast Piles
- Duplex Rotary – Aggressive Cutting Shoes
- Single #75mm Bar
- Cased to rock – bond in socket

# Looks Pretty Similar

## Where do we Differ??

### Australian Market:

- Not well established in engineering practice – Market Size!
- Used as a last resort – preference for conventional piling techniques
- Typically proposed by contractor as alternative
- Often due to access and headroom restrictions
- Designed to AS2159 or Project / Client specific design requirements
- Material Supply – ARCS Certified Mills
- Asian and European Suppliers – 6 week lead times

### North American Market:

- Well established method in engineering practice – Market Size!
- Typically driven by geotechnical conditions
- Designed to SA-097-070 or to the IBC with local building codes and geotechnical best practice
- Value Engineering Options
- Material Supply – Buy American/America / Prime Vs Mill Second Pipe
- Domestically Sourced – short lead times

# Design and Testing

## Standards/Guidelines:

### Australian Market:

- **AS 2159-2009** (Civil Engineering and Building) and **AS 5100.3-2017** (Bridges),
- ✓ Not micropile specific. A small reference to small diameter displacement piles (<0.3m) only,
- ✓ Standard to be used in conjunction with other AS standards (AS3600, AS4100, AS1170),
- ✓ Factor of safety is risk dependent,
- ✓ Uses Limit State approach (SLS, ULS).

### North American Market:

- Federal Highway Administration Manuals,
- ✓ **SA-97-070 Design and Construction of Micropiles (2000),** NHI-05-039 Micropile Design and Construction (2005),
- ✓ Developed specifically for Micropiles,
- ✓ Covers application, design, drilling methods, construction and testing,
- ✓ Two design approaches: Service Load Design (SLD) and Load Factor Design (LFD).

# Design and Testing

## Structural Capacity:

### Australian Market:

- *Reinforced concrete: (AS 3600: 2018)*

$$R_{d,s}=\phi_s k R_{us}$$

$\phi_s$ = 0.65 and 0.85 in compression and tension
Design strength of concrete = 0.72 to 0.85 times $f'_c$
k = 0.75 to 1.0 (assume 1.0)

- *Steel: (AS 4100-1998)*

$$R_{d,s}=\phi_s R_{us}$$

$\phi_s$ = 0.9 in compression in tension

✓ Overall FS ($1.35/\phi_s$) **~ 1.5 to 2.5 (c), 1.5 to 1.6 (t)**

✓ FS will be higher if k=0.75 would be used.

✓ Combined load factor (DL+LL) of 1.35 was used, if majority of the load is LL, than FS would be similar.

### North American Market:

- SLD Method (most common):

In compression: $0.40\ f_{y\text{-}grout} + 0.47\ f_{y\text{-}steel}$

In tension: 0.55 $f_{y\text{-steel}}$

✓ Overall FS (1/factor) = **2.12 (c), 1.8 (t)**

# Design and Testing

## Geotechnical Capacity:

### Australian Market:

- *General*

$$R_{d,g}=\phi_g R_{d,ug}$$

$\phi_g$ = 0.61 and 0.70 in compression and tension

$\phi$ = 0.8 additional factor for piles tension commonly used but not directly required by AS2159

ARR assumed as 1.5 to 2.0,

- ✓ Overall FS (1.35/$\phi_g$) **~ 2.21 to 2.8**
- ✓ AS does not provide guidance on grout-ground bond capacities. Local geotechnical knowledge is required (eg. Pells et al. 2019).

### North American Market:

- SLD Method (most common):

$$P_{G\text{-}allowable}=\alpha_{bond}/FS \times \pi \times D_b \times L_b$$

FS = 0.5 in compression and tension

$\alpha_{bond}$ – Ground to grout bond capacity

$D_b \times L_b$ – Micropile diameter and length of bonded section

- ✓ Overall FS = **2.0**
- ✓ FHWA provides expected ground to grout bond capacities based on drilling techniques

# Design and Testing

| Section | Australian Market: AS 2159 (2009) | North American Market: SA-97-070 (2000) |
|---|---|---|
| Group of micropiles<br>- Minimal spacing 3.0D to avoid group effect reduction. | In addition to other relevant design actions, pile to be designed for a bending moment Cl. 5.2.2<br>$N_d$ x 0.05D<br>(min. any pile and with depth) | No additional bending moment to be accounted for if 3 or more MPs are used.<br>Efficiency factor to be considered for block failure if MPs spacing is < 3D |
| Performance | Not specified. Determined by Engineer.<br>Default testing acceptance criteria 1%D + Elastic deformation under SLS | The Owner to provide specific performance criteria (e.g., movement of structure) |
| Corrosion Protection:<br>Assume: Design Life 100y and serve exposure classification | Concrete: 50MPa and 100mm cover,<br>Steel: 4mm to 10mm section corrosion loss | Grout cover – min. 25mmin soil and 12.5mm in rock.<br>Other conventional corrosion protection also specified (e.g. corrosion allowance for steel casing, encapsulation, coating) |
| Buckling | For freestanding portion or in very soft soils<br>**No guideline on design** | **Very specific design** consideration for very weak or liquefiable soils:<br>$P_{cr} = \pi^2 EI / L^2 + E_s L^2 / \pi^2$ |
| Grout to Steel Bond Capacity<br>Drives length of micropile | **< 2.0MPa** (max) AS 3600 (deformed bars)<br>Based on concrete – neat w/c grouts not considered | 1.0MPa to 1.75MPa – smooth bars/pipes<br>2.0MPa to **3.5MPa** – deformed bars |
| Slope Stability | N/A | Chapter 6 provides detailed guidance on design miropiles for slope stability applications |

## Design and Testing

### Impact Of Pile Group Eccentricity Design Requirement:

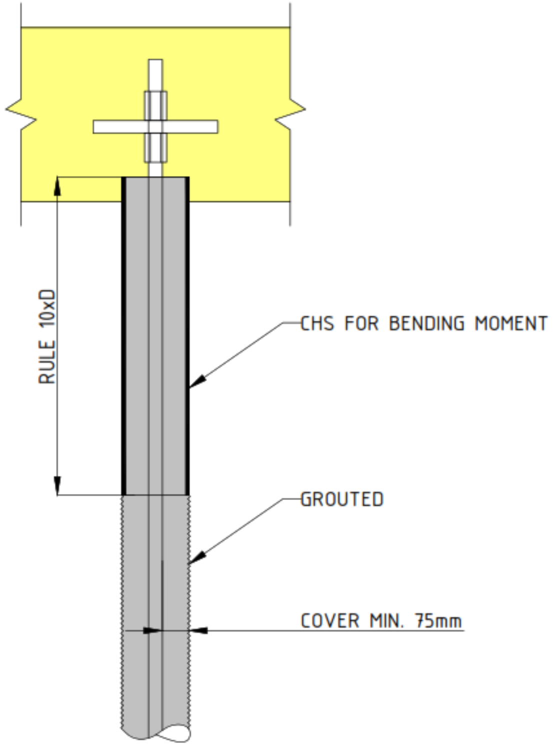
➢ Additional Permanent Casing Within Top Section of Pile

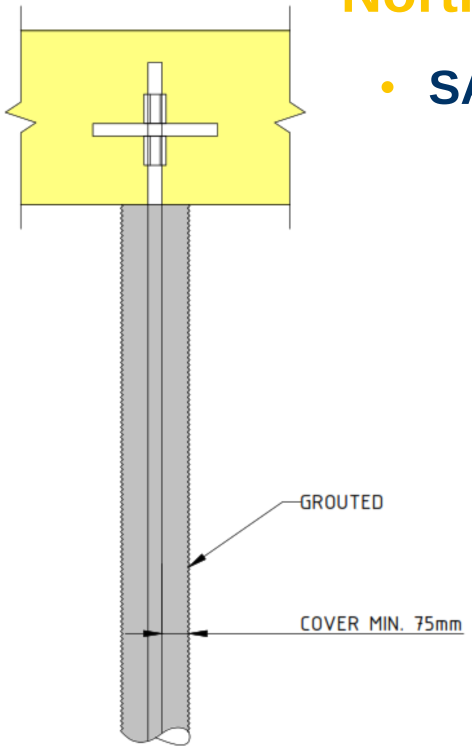
**Australian Market:**

- **AS 2159-2009**

**North American Market:**

- **SA-97-070**



# Design and Testing

## Testing:

**Australian Market:** | **North American Market:**

| Section | AS 2159 | SA-97-070 (2000) |
|---|---|---|
| Project: Assume number of piles less than 249 No. | Testing requirements not based on size of the project. Testing/No testing will affect safety factor by approx. 10% to 15% | FHWA – dependant no. piles. Table 7-1 to 80% of steel yield capacity |
| Ultimate (sacrificial pile) DL (working) | Optional (to grout-to-ground failure) Commonly on small diameter and reduced bond length (~3m) | Optional (to grout-to-ground failure) |
| Verification (sacrificial pile) | $1.35/\phi_g$ x DL ~ 2.5 x DL (up to designer and project risk rating) | 2.5 x DL (1 No.) |
| Proof (production pile) | N/A | 1.67 x DL (<5%) |
| Serviceability (production pile) | 1.0 x DL 1% to 3% of MPs (typical, depending on ARR) | N/A |
| Creep (all) | Required in Clays or long time settlements – if bond length in creep sensitive ground | At constant test load with maximum 2mm/log cycle is common acceptance criteria |

# Design and Testing

## Summary:

- **AS 2159-2009:**

✓ Not specific for micropiles, lack of design specific elements,
✓ Factor of safety is risk dependent (ARR),
✓ Multiple cross reference to other Australian Standards,
✓ Outcome can be very onerous if specific clauses are adopted (Cl. 5.2.2),
✓ Structural design is more lenient over FHWA – driven by our material certification process (no mill 2nd pipe)
➢ **Time to develop a micropile specific code/guideline?**

- **FHWA:**

✓ Comprehensive document for miropiles design, construction and testing,
✓ Factor of safety is fixed and mandatory testing project dependent (No. of MPs),
✓ Geotechnical design is more favourable over AS,
✓ Much favourable in regard to corrosion protection. Smaller diameter can be used.
➢ **Take full advantage of a developed market and drive further innovation**


# Thank you