Brian Perry Civil
Diaphragm & Secant Pile Walls

by
Nick Wharmby
Focus of the Presentation

- Diaphragm Walls
- Secant Piles
# Wall Options / Selection

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Sheetpile Wall</th>
<th>Secant Piles Wall</th>
<th>Cutter SoilMix Wall</th>
<th>Slurry Wall</th>
<th>Diaphragm Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Proven in NZ</td>
<td>Proven in NZ</td>
<td>Site specific trial required</td>
<td>Proven in NZ</td>
<td>Proven in NZ</td>
</tr>
<tr>
<td>Specialist plant</td>
<td>Widely available in NZ</td>
<td>Available in NZ</td>
<td>Available offshore</td>
<td>Readily available</td>
<td>Readily available</td>
</tr>
<tr>
<td>Environment - Noise</td>
<td>Yes, unless Giken or similar</td>
<td>Machine only</td>
<td>Machine only</td>
<td>Machine only</td>
<td>Machine only</td>
</tr>
<tr>
<td>- Vibration</td>
<td>Yes, unless Giken or similar</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>- Spoil</td>
<td>No</td>
<td>100%</td>
<td>30 - 40%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Construction - Establishment</td>
<td>Cranes, vibros and hammers and / or pile jacking plant (Giken)</td>
<td>50-60T self erecting hydraulic drilling rigs and handling crane.</td>
<td>90T CSM machine, handling crane, 15m³/hr grout plant with screw feed silos, compressor, high pressure pumps</td>
<td>50T crane + grab, handling crane, long-reach excavator, 15m³/hr grout plant with screw feed silos</td>
<td>50T crane + grab, handling crane, mud conditioning plant, mud storage</td>
</tr>
<tr>
<td>- Material to site</td>
<td>Sheet piles</td>
<td>Concrete, reinforcement cages</td>
<td>Cement, bentonite, steel</td>
<td>Cement, bentonite, steel or precast concrete panels</td>
<td>Bentonite, reinforcement cages or precast concrete panels</td>
</tr>
<tr>
<td>- Work face access</td>
<td>Plant &amp; Materials delivery</td>
<td>Plant &amp; Materials delivery</td>
<td>Plant, materials and pipeline delivery of grout</td>
<td>Plant, materials and pipeline delivery of slurry</td>
<td>Plant, materials and pipelines for Bentonite mud circulation</td>
</tr>
<tr>
<td>- Programme flexibility</td>
<td>Can easily increase the number of rigs to accelerate</td>
<td>Significant further mobilisation</td>
<td>Can easily increase the number of rigs to accelerate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product - Wall movement</td>
<td>Flexible</td>
<td>Very stiff</td>
<td>Stiff (depends on steel section)</td>
<td>Stiff (depends on steel section)</td>
<td>Very stiff</td>
</tr>
<tr>
<td>- Watertightness</td>
<td>Good with joint treatment</td>
<td>Satisfactory but some seepage</td>
<td>Satisfactory but some seepage</td>
<td>Good due to total replacement with low permeability CB slurry</td>
<td>Excellent with waterbar across panel joints</td>
</tr>
<tr>
<td>- Connections</td>
<td>Welded below capping beam level</td>
<td>Drilled &amp; grouted bars + waterstop</td>
<td>Welded below capping beam level, bending moment possible</td>
<td>Welded below capping beam level, bending moment possible</td>
<td>Full moment &amp; shear connection via box-out and pull-out bars</td>
</tr>
<tr>
<td>- Durability</td>
<td>Internal painting and sacrificial thickness of steel</td>
<td>Conventional concrete in the ground design. Internal lining for long-term seepage</td>
<td>Sacrificial thickness of steel and internal lining wall for ground water</td>
<td>PC panels would negate sacrificial thickness of steel and internal lining wall</td>
<td>Conventional concrete in the ground design. No internal lining necessary</td>
</tr>
<tr>
<td>- Load capacity</td>
<td>Low end bearing capacity</td>
<td>Capacity can be enhanced by rock socket formation</td>
<td>Capacity limited by penetration of steel beams</td>
<td>Capacity limited by penetration of steel beams</td>
<td>Wall can be formed with nominal rock socket over large area</td>
</tr>
</tbody>
</table>
Diaphragm Walls – Layout & Joint

- Panels excavated under support fluid (bentonite)
- Reinforced concrete panels cast using tremie
- Waterstop included across panel joints
Diaphragm Walls - Panel Joints
Diaphragm Wall - Joints

- Wall joint waterbar
- Slab connection
  - Waterbar / waterstop
  - Breakback cracking
  - Waterbar / slab pathway
Diaphragm Walls - Trench Stability
Diaphragm Walls – Trench Stability

SPT “N” value

Su – Vane tests

Su Remoulded
Diaphragm Walls - Trench Stability

**Panel / Bore Stability Assessment:**

**Location:** Trench Stability - General 7.0m wide panel

- Panel length / Bore diameter, B (m) = 7.000
- Depth to Groundwater level (m) = 1.500
- Depth to Bentonite [ve above G.L.] (m) = 0.500
- Surcharge at ground level (KN/m²) = 0.000

**Stratigraphy / Soil Parameters**

<table>
<thead>
<tr>
<th>Strata Description</th>
<th>Depth to strata (m)</th>
<th>Density ( \gamma ) (KN/m³)</th>
<th>Effective ( \phi' ) (degs)</th>
<th>Effective ( c' ) (KPa)</th>
<th>Total ( C_u ) (KPa)</th>
<th>( C_u/ z ) (KPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidewalls</td>
<td>0.0</td>
<td>17</td>
<td>30</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alluvial Clay (TG)</td>
<td>1.2</td>
<td>17</td>
<td>0</td>
<td>0.0</td>
<td>15</td>
<td>-2</td>
</tr>
<tr>
<td>Alluvial Clay (TG)</td>
<td>3.0</td>
<td>17</td>
<td>0</td>
<td>0.0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Alluvial Clay (TG)</td>
<td>6.0</td>
<td>17</td>
<td>0</td>
<td>0.0</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>All Silt/Sand (TG)</td>
<td>10.0</td>
<td>17</td>
<td>30</td>
<td>10.0</td>
<td>15</td>
<td>-2</td>
</tr>
<tr>
<td>All Silt/Sand (TG)</td>
<td>14.0</td>
<td>17</td>
<td>30</td>
<td>15.0</td>
<td>20</td>
<td>-2</td>
</tr>
</tbody>
</table>

Soil arching around a slurry trench

[Brian Perry Civil](https://www.brianperrycivil.co.nz)
Diaphragm Walls - Trench Stability

Stability Assessment Graph

Active Pressure
Bentonite Pressure
Diaphragm Walls - Trench Stability

Stability Assessment Graph

- Add 10KPa surcharge
- Minimum Guidewall depth
- Potentially Unstable
- 1.0m drop in Bentonite level
Diaphragm Walls - Trench Stability

- Maintaining a positive fluid pressure
  - Minimise fluid loss into soil
  - Formation of “Filter cake” or effective “Membrane”
- Maintaining support fluid quality

Support fluid pressure <= water pressure
>> INSTABILITY
Diaphragm Walls - Trench Stability

Assessment of Ground Bearing Pressures

Crane Weight 106800 kg
Boom Length 20 m
Load (Incl hook) 25.0 t
Max. Radius 13 m
Total / Gross Load 131800.0 kg

Nearest Chart Radius with this load = 12 m
Chart Load at this Radius = 29.7 t
Tipping Load at this Radius = 39.6 t

Effective Eccentricity under Load at Max. Radius = 1.04 m

<table>
<thead>
<tr>
<th>Track / Body Slew (Degrees)</th>
<th>Bearing Pressures (KPa)</th>
<th>RH Track Loading</th>
<th>RH Track Dimensions (m)</th>
<th>Equiv Rectangular Dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RH Track Front (KPa)</td>
<td>Front (KPa)</td>
<td>Rear (KPa)</td>
<td>Length (m)</td>
</tr>
<tr>
<td></td>
<td>RH Track Rear (KPa)</td>
<td>Rear (KPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>252</td>
<td>0</td>
<td>252</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>223</td>
<td>0</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>273</td>
<td>0</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>281</td>
<td>0</td>
<td>213</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>288</td>
<td>0</td>
<td>199</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>292</td>
<td>0</td>
<td>185</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>295</td>
<td>3</td>
<td>172</td>
<td>2</td>
</tr>
<tr>
<td>35</td>
<td>296</td>
<td>11</td>
<td>158</td>
<td>6</td>
</tr>
<tr>
<td>40</td>
<td>295</td>
<td>21</td>
<td>145</td>
<td>10</td>
</tr>
<tr>
<td>45</td>
<td>292</td>
<td>32</td>
<td>133</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>286</td>
<td>45</td>
<td>121</td>
<td>19</td>
</tr>
<tr>
<td>55</td>
<td>279</td>
<td>59</td>
<td>110</td>
<td>23</td>
</tr>
<tr>
<td>60</td>
<td>269</td>
<td>74</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>65</td>
<td>258</td>
<td>91</td>
<td>91</td>
<td>32</td>
</tr>
<tr>
<td>70</td>
<td>245</td>
<td>108</td>
<td>82</td>
<td>36</td>
</tr>
<tr>
<td>75</td>
<td>230</td>
<td>126</td>
<td>74</td>
<td>41</td>
</tr>
<tr>
<td>80</td>
<td>214</td>
<td>144</td>
<td>67</td>
<td>45</td>
</tr>
<tr>
<td>85</td>
<td>198</td>
<td>162</td>
<td>61</td>
<td>50</td>
</tr>
<tr>
<td>90</td>
<td>180</td>
<td>180</td>
<td>55</td>
<td>55</td>
</tr>
</tbody>
</table>

Stress (KPa)

sz
sx

[Diagram showing stress vs. distance with curves for different stresses and angles]

right from the start : www.brianperrycivil.co.nz
Diaphragm Walls - Site Layout

Mayfair, London
Diaphragm Walls – Conditioning Plant

New Lynn Rail Trench
Diaphragm Walls – Conditioning Plant

New Lynn Rail Trench
Diaphragm Walls - Guide walls

New Lynn Rail Trench

Lancashire

right from the start: www.brianperrycivil.co.nz
Diaphragm Walls – Rope Grab

New Lynn Rail Trench

right from the start: www.brianperrycivil.co.nz
Diaphragm Walls – Hydraulic Grab

New Lynn Rail Trench

right from the start : www.brianperrycivil.co.nz
Diaphragm Wall - Reinforcement

- Detailing
- Fabrication
- Transportation
- Lifting
- Connections

New Lynn Rail Trench
Diaphragm Walls - Reinforcement

New Lynn Rail Trench
Diaphragm Walls - Reinforcement

New Lynn Rail Trench
Diaphragm Walls
- Reinforcement

• Tolerances for built in connections
• Boxouts
• Cracking during breakout
• Waterstop / waterbar
Diaphragm Walls - Reinforcement
Diaphragm Walls - Exposed Wall
Diaphragm Walls - Exposed Wall

Haverigg

right from the start: www.briannperrycivil.co.nz
Diaphragm Walls - Exposed Wall

Mayfair Car Park
Diaphragm Walls - Exposed Wall

New Lynn Rail Trench

right from the start: www.brianperrycivil.co.nz
Diaphragm Walls - Exposed Wall

New Lynn Rail Trench

right from the start : www.brianperrycivil.co.nz
Diaphragm Walls - Exposed Wall

New Lynn Rail Trench

right from the start : www.brianperrycivil.co.nz
Secant Pile Walls

- Low Strength Concrete Firm piles
- Reinforced concrete Hard piles
- Flexible wall layout
- Use of CFA methods is possible
Secant Pile Walls

Maintaining overlap
- Plan position
  - guide wall
- Verticality
  - Strength of “soft” mix
  - Sequence of pile construction
  - effect of obstructions
Secant Pile Walls

- SPERW (2nd Edition 2007) Pile Overlap

### Table C9.1 Secant pile wall verticality tolerances

<table>
<thead>
<tr>
<th>Piling method</th>
<th>Verticality</th>
<th>Depth of pile interlock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous flight auger (CFA) using standard or heavy duty augers</td>
<td>1:75</td>
<td>0–5 m</td>
</tr>
<tr>
<td>CFA using extra heavy duty augers*</td>
<td>1:125</td>
<td>0–7 m</td>
</tr>
<tr>
<td></td>
<td>1:75</td>
<td>7–10 m</td>
</tr>
<tr>
<td>Cased CFA</td>
<td>1:150</td>
<td>0–15 m</td>
</tr>
<tr>
<td>Bored cast-in-place using standard tools</td>
<td>1:100</td>
<td>0–7 m</td>
</tr>
<tr>
<td>Bored cast-in-place using stiffened casings with cutting teeth</td>
<td>1:200</td>
<td>0–20 m</td>
</tr>
</tbody>
</table>

*Augers comprising thickened stems
Secant Pile Wall – Guide walls

Tauranga

Manukau

right from the start : www.brianperrycivil.co.nz
Secant Pile Walls - Concrete Mix

- **Constructional**
  - placement
  - drillability
  - seepage control

- **Structural**
  - Strength
  - durability
Secant Pile Walls - Concrete Mix

- Soft / Firm Mix Trials

200KPa
Secant Pile Walls – Soft mix

- Strength of “soft” mix
  - Fit for purpose
- Infill between piles
- Unreinforced
- Strength & Batching variance of small quantities
## Secant Pile Walls - Hydraulic Rigs

<table>
<thead>
<tr>
<th>Rig</th>
<th>Weight (T)</th>
<th>Power (KW)</th>
<th>Torque (KNm)</th>
<th>Max. Pile Diameter (m)</th>
<th>Max. Pile Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoDril</td>
<td>40</td>
<td>209</td>
<td>68</td>
<td>1.2</td>
<td>24</td>
</tr>
<tr>
<td>SR30</td>
<td>37</td>
<td>205</td>
<td>130</td>
<td>1.5</td>
<td>48</td>
</tr>
<tr>
<td>R516</td>
<td>54</td>
<td>230</td>
<td>180</td>
<td>2.0</td>
<td>44</td>
</tr>
<tr>
<td>SR50</td>
<td>54</td>
<td>230</td>
<td>180</td>
<td>2.0</td>
<td>61</td>
</tr>
<tr>
<td>R625</td>
<td>70</td>
<td>300</td>
<td>240</td>
<td>2.5+</td>
<td>77+</td>
</tr>
</tbody>
</table>
Secant Pile Walls - Hydraulic Rigs

Newmont Gold, Waihi

BNZ, Auckland

right from the start: www.brianperrycivil.co.nz
Secant Pile Walls

BNZ Auckland
Secant Pile Walls

BNZ Auckland

right from the start: www.brianperrycivil.co.nz
Secant Pile Walls

right from the start: www.brianperrycivil.co.nz
Secant Pile Walls

Manukau

right from the start: www.brianperrycivil.co.nz
Secant Pile Walls

• Time to watch a short video clip
Secant Pile Walls

Particular attention is required to ensure that bars are not so closely spaced or arranged that they prevent proper flow and compaction of the concrete. A clear bar spacing of 100 mm should be regarded as the minimum requirement for vertical bars and 175 mm for horizontal bars. If piles are constructed with support fluid then larger clear bar spacings are encouraged.

SPERW 2nd Edition 2007 Cl. C9.4.4
Secant Pile Walls

BNZ Auckland
Secant Pile Walls – Waterproof lining

- Fixing membrane
- Swelling constraint
CFA Secant Pile Walls

- Boring
  - Flighting
  - Polishing
  - Loosening
- Concreting
  - Poor base
  - Necking
  - Blockages
- Cage insertion
# CFA Bored Piles

<table>
<thead>
<tr>
<th>Ground Conditions</th>
<th>Drill</th>
<th>Conc.</th>
<th>Cage</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Very Soft Clays</td>
<td>✅✅✅</td>
<td>✗</td>
<td>✅</td>
<td>Concrete instability / integrity</td>
</tr>
<tr>
<td>2. Soft to Stiff Silts / Clays</td>
<td>✅✅✅</td>
<td>✅✅✅</td>
<td>✅✅✅</td>
<td></td>
</tr>
<tr>
<td>3. Very Loose / Loose Sands</td>
<td>✅✅✅</td>
<td>✅✅✅</td>
<td>✗</td>
<td>High permeability can make cage insertion problematic</td>
</tr>
<tr>
<td>4. Dry Sands / Sandstones</td>
<td>✅✅✅</td>
<td>✅</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>5. Dense Wet Sands</td>
<td>✅✅✅</td>
<td>✅</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Gravels &amp; Cobbles &lt;150mm</td>
<td>✅</td>
<td>✅✅✅</td>
<td>✗</td>
<td>OK provided material will flight</td>
</tr>
<tr>
<td>7. Boulders</td>
<td>✗</td>
<td>✅✅</td>
<td>✅</td>
<td>Obstruct or deflect auger</td>
</tr>
<tr>
<td>8. Weak Rocks &lt;5MPa</td>
<td>✅</td>
<td>✅</td>
<td>✗</td>
<td>Rock head and pull down required</td>
</tr>
<tr>
<td>9. Moderately Strong Rocks &gt;5MPa</td>
<td>✗</td>
<td>✅</td>
<td>✗</td>
<td>Refusal and reduced friction</td>
</tr>
<tr>
<td>10. Voided Ground</td>
<td>✅✅✅</td>
<td>✗</td>
<td>✗</td>
<td>Integrity, loss of concrete</td>
</tr>
<tr>
<td>11. Soft / Loose over hard</td>
<td>✗</td>
<td>✅</td>
<td></td>
<td>Flighting, settlement &amp; void potential</td>
</tr>
</tbody>
</table>

- ✅✅✅ = No real Issues to ✗ = particular care required,
- ✗ ✗ ✗ ✗ = potentially significant issues, refer to Manager Engineering for mitigation measures / alternatives

“If in doubt  ASK”
## CFA Bored Piles

<table>
<thead>
<tr>
<th>Rig</th>
<th>Weight (T)</th>
<th>Torque (KNm)</th>
<th>Max. Pile Diameter (m)</th>
<th>Max. Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR30</td>
<td>36</td>
<td>121</td>
<td>0.75</td>
<td>18.5</td>
</tr>
<tr>
<td>SR50</td>
<td>53</td>
<td>180</td>
<td>0.60/0.90</td>
<td>21.0/18.0</td>
</tr>
</tbody>
</table>
CFA Bored Piles

- Real time monitoring during construction
- Operators guide
- Quality records
CFA Secant Pile Walls

Ellerslie & Shaddock (173K)
CFA Secant Pile Walls

• Key Factors
  – Soft pile mix
  – Auger string
  – Pile layout
  – Boring head
CFA Secant Pile Walls

Maleme St, Tauranga

right from the start: www.brianperrycivil.co.nz
CFA Secant Pile Walls

Maleme St, Tauranga

right from the start: www.brianperrycivil.co.nz
CFA Secant Pile Walls

Maleme St, Tauranga
CFA Secant Pile Wall - Arched

- Soil Load applied to wall piles
- Arched “Firm” piles distribute the load to the “Hard” piles
- Stability provided by embedment and structural capacity

Typical section through wall
CFA Secant Pile Wall - Arched
SPERW
2nd Edition 2007

• Client, Consultant & Contractor developed
• Specifications
• Construction guidelines

“If in doubt ASK”
Key Points

• Diaphragm and secant pile walls are proven methodologies in NZ
• CFA methods have been developed to enable secant pile wall construction
• ICE Specification advocated

“THANK YOU”