USE OF DIPP PILES FOR A NEW SUP BRIDGE IN WEST MELBOURNE

Michael Wei, Jawad Zeerak & David Barton
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1.0 PROJECT OVERVIEW
Project Location

- The project is located approx. 5km to the west of Melbourne CBD
- The new SUP Bridge is constructed over the Maribyrnong River
The new SUP Bridge was constructed over the Maribyrnong River to improve the amenity for cyclists.

It replaces the existing SUP on the adjacent Shepherd’s Bridge.

Existing SUP on the Shepherd Bridge was removed, Shepherded Bridge was widened and strengthened to support the increased freight movement to the port of Melbourne as part of West Gate Distributor – Stage 1 project.

The river crossing is one of the busiest cycle routes around the Melbourne.
The New SUP Bridge

- The bridge is 3 span, 190m long and 4.5m wide
- Supported on two abutments (east & west) and two piers (east & west)
2.0 GEOTECHNICAL CONDITIONS
Geotechnical Conditions

- The bridge is located in the Yarra Delta region of Melbourne

- The major geological units included:
  - Fill
  - Coode Island Silt (CIS)
  - Fishermens Bend Silt (FBS)
  - Newer Volcanics Basalt
Geotechnical Conditions…cont’d
3.0 DUCTILE IRON PIPE PILES (DIPPS)
Ductile Iron Pipe Piles (DIPPs)

- During the tender & preliminary design stages CFA piles were proposed to support the new SUP Bridge
- During later stages of the design DIPPs were adopted as alternative foundation piles for the following reasons:
  - Limited rig capacity to install over 30m long CFA piles
  - Site constraints (existing bridge) including presence of services
  - Light weight and more mobile installation equipment & less vibration
- DIPPs were for the first time used on a VicRoads project
DIPPs Cont’d

- DIPPs are circular tube piles made of ductile cast iron
- 170mm dia piles with 9mm wall thickness
- 5m long sections installed using plug & drive
- 900MPa compressive strength and 420MPa tensile strength
- Load of up to 2400kN
- The piles are filled with 50MPa concrete
- 5m long 100 UC sections inserted for the top section
- High corrosion resistant than steel
- Low vibration (<= 2mm/sec)
- Can be installed 400mm from existing buildings
- Driven using standard 25-30t excavator mounted with hydraulic hammer
DIPPs Cont’d 2

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Pile driving video
DIPPs Cont’d 2
4.0 PILE DESIGN & PILE GROUP ANALYSIS
The DIPPs were arranged in the following groups:

- **Abutments**
  - 8 piles (two groups of 4)

- **East Pier**
  - 12 Piles (Two rows of 5 piles with an additional two piles)

- **West Pier**
  - 19 Piles

- Due to presence of services & eccentric loading, west pier was arranged in the above manner.
Foundation layout

WEST ABUTMENT
(8 PILES)

WEST PIER 2
(19 PILES)

EAST PIER 1
(12 PILES)

EAST ABUTMENT
(8 PILES)

APPROXIMATE LOCATION
OF EXISTING OIL LINE

DAMAGED PILE
FILLED WITH
CONCRETE

CONTROL LINE
Pile Group Analysis

- Original design proposed 900dia CFA piles,
- Detailed design adopted 170mm dia DIPPs
- DIPPs are long and slender
- Concerns associated with lateral capacity of DIPPs
- The lateral loads were mainly due to wind and earthquake
- It was crucial that an accurate assessment of the lateral loads was undertaken

- Pile groups were analysed using the following two methods;
  - PIGLET
  - PLAXIS 3D
Pile Loads

- Two load cases were analysed

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Vertical Load (kN)</th>
<th>Horizontal Load (kN)</th>
<th>Moment (kN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8390</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6015</td>
<td>500</td>
<td>4100</td>
</tr>
</tbody>
</table>

- Case 1 governed vertical load case while case 2 governed lateral load cases
PIGLET

- PIGLET is a spreadsheet based program
- Relatively easy to use and quick answer
- Limitation of PIGLET e.g. one single soil layer, soil strength cannot be modelled
- Due to ease of use and quick results, PIGLET is still commonly used

- The following soil parameters were used in the PIGLET analysis

<table>
<thead>
<tr>
<th>Soil Parameters</th>
<th>Pile Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Modulus (kPa)</td>
<td>Shear Modulus Gradient (kPa/m)</td>
</tr>
<tr>
<td>2,310</td>
<td>500</td>
</tr>
</tbody>
</table>
PLAXIS 3D

- PLAXIS 3D is a 3D FEA package
- Used for deformation and stability analysis
- In PLAXIS 3D, the 170 dia DIPP piles were modelled as ‘embedded beam’ elements
- Pile cap was modelled as linear elastic plate element
- The following geotechnical parameters were adopted in the analysis

<table>
<thead>
<tr>
<th>Material/Layer</th>
<th>$\gamma$ (kN/m³)</th>
<th>$C_u$ (kPa)</th>
<th>$C'$ (kPa)</th>
<th>$\Phi'$ (degree)</th>
<th>$E'$ (kPa)</th>
<th>$\nu'$</th>
<th>Ult. Skin Friction (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill</td>
<td>18</td>
<td>75</td>
<td>5</td>
<td>25</td>
<td>25,000</td>
<td>0.35</td>
<td>40</td>
</tr>
<tr>
<td>CIS</td>
<td>17</td>
<td>25</td>
<td>2</td>
<td>25</td>
<td>2,500</td>
<td>0.35</td>
<td>-</td>
</tr>
<tr>
<td>FBS Upper, stiff silty clay</td>
<td>18</td>
<td>75</td>
<td>5</td>
<td>26</td>
<td>25,000</td>
<td>0.35</td>
<td>40</td>
</tr>
<tr>
<td>FBS silty/clayey sand</td>
<td>19</td>
<td>-</td>
<td>3</td>
<td>28</td>
<td>30,000</td>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>FBS lower, very stiff silty clay</td>
<td>19</td>
<td>100</td>
<td>10</td>
<td>26</td>
<td>30,000</td>
<td>0.35</td>
<td>50</td>
</tr>
<tr>
<td>Basalt</td>
<td>26</td>
<td>-</td>
<td>50</td>
<td>33</td>
<td>100,000</td>
<td>0.2</td>
<td>600</td>
</tr>
</tbody>
</table>
To following stages were included in the PLAXIS 3D analysis to simulate the construction sequence on site:

- Generate initial stresses
- Install piles
- Excavate to the base of pile cap
- Construct Pile cap
- Apply bridge load
### Pile Group Analyses Results (east pier)

<table>
<thead>
<tr>
<th>Pile No</th>
<th>Axial Force (kN/pile)</th>
<th>Max Bending Moment (kN-m)</th>
<th>Pile Head Settlement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PIGLET</td>
<td>PLAXIS 3D</td>
<td>PIGLET</td>
</tr>
<tr>
<td>1</td>
<td>385</td>
<td>347</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>312</td>
<td>340</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>293</td>
<td>338</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>312</td>
<td>341</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>385</td>
<td>351</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>734</td>
<td>668</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>614</td>
<td>665</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>583</td>
<td>655</td>
<td>28</td>
</tr>
<tr>
<td>9</td>
<td>614</td>
<td>655</td>
<td>29</td>
</tr>
<tr>
<td>10</td>
<td>734</td>
<td>668</td>
<td>33</td>
</tr>
<tr>
<td>11</td>
<td>524</td>
<td>520</td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>524</td>
<td>520</td>
<td>31</td>
</tr>
</tbody>
</table>

- Calculated pile actions and pile settlements from PIGLET & PLAXIS are generally in the similar range.
- Pile head settlements under serviceability load conditions were well below the acceptance criteria.
Pile deflection & moment – PLAXIS 3D

- Calculated bending moments were generally in the top 4m and dropped to virtually nothing at depth of approx. 4m

- Based on this top 5m of the DIPPs were reinforced with UC section
Settlement contours – PLAXIS 3D

- As shown pile toe movement is negligible, indicating that the pile head settlement were predominantly due to elastic shortening of the piles.
Geotechnical capacity – PLAXIS 3D

- The pile geotechnical capacity was mainly derived from shaft resistance
- As shown, mobilised toe resistance from PLAXIS 3D were very small
- The pile end bearing is not fully mobilised (small movements shown before)
5.0 PILE LOAD TESTING
Pile Tests & Results

- Six piles were tested using dynamic load testing with PDA & CAPWAP analysis;
  - 1 at each abutment
  - 2 at each piers

- Pile Test results are presented below

<table>
<thead>
<tr>
<th>Test Pile ID</th>
<th>Pile Length (m)</th>
<th>Ultimate Geotechnical Strength (kN)</th>
<th>Test Load from PDA (kN)</th>
<th>Test Load from CAPWAP (kN)</th>
<th>Total Shaft Resistance (kN)</th>
<th>Mobilised Toe Resistance (kN)</th>
<th>Pile Head Settlement at design Load (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2EA</td>
<td>29.5</td>
<td>430</td>
<td>1242</td>
<td>1224</td>
<td>1183</td>
<td>41</td>
<td>3</td>
</tr>
<tr>
<td>1EP</td>
<td>29.9</td>
<td>1340</td>
<td>1703</td>
<td>1850</td>
<td>1698</td>
<td>152</td>
<td>13</td>
</tr>
<tr>
<td>2EP</td>
<td>29.8</td>
<td>1340</td>
<td>1857</td>
<td>2076</td>
<td>1850</td>
<td>226</td>
<td>13</td>
</tr>
<tr>
<td>7WP</td>
<td>11.5</td>
<td>1380</td>
<td>2063</td>
<td>2180</td>
<td>2010</td>
<td>170</td>
<td>7</td>
</tr>
<tr>
<td>8WP</td>
<td>7.6</td>
<td>1380</td>
<td>1538</td>
<td>1568</td>
<td>1286</td>
<td>282</td>
<td>8</td>
</tr>
<tr>
<td>3WA</td>
<td>11.3</td>
<td>740</td>
<td>1528</td>
<td>1584</td>
<td>803</td>
<td>780</td>
<td>4</td>
</tr>
</tbody>
</table>

- All tested piles exceeded the required geotechnical capacity
Pile Load Testing

- During the design stage, refusal in basalt was assumed at 60mm/ 30sec of driving (contractor’s experience)

- Based on actual pile driving records refusal was achieved at less than 12mm/ 30sec

- Test results indicated significantly higher shaft resistance than expected, particularly at the west abutment (up to 300-600kPa)

- The above could be attributed to presence of XW-HW basalt which may have been penetrated through during the driving process

- All tested piles exceeded the required ultimate geotechnical capacity

- Settlements under serviceability loads were well below the criteria

- With the above DIPP piles were successfully used for the first time on a VicRoads Project.
Construction Photos
Lifting in place of the superstructure
Acknowledgments