

DESIGN OPTIMISATION OF TEMPORARY WORKING-PLATFORMS

Amelia Gilbert-Milne

Katarzyna Anna Zamara

Martin Larisch

Ryan Yan

ABSTRACT

Temporary working-platforms have significant cost implications in the construction industry. Working-platforms are required on almost every infrastructure project either for piling-rigs or for mobile/crawler-cranes, to lift up and install structural components. The cost associated with the material and the resource needed to build working-platforms is significant. Further, these costs increase if a platform fails and a crane or rig falls over. More importantly there are extreme health and safety issues associated with such an event. Incidents of this nature are not uncommon in the industry as often platform designs are not acquired or corners are cut during platform construction. In global literature there is little research into temporary working-platforms performance and design. Therefore current design methods are considered to be conservative by practitioners and thus expensive to build. This paper describes a study that has been carried out to investigate the performance of a temporary working-platform. The platform has been designed and built with state-of-the-art geotechnical monitoring instrumentation installed. Instrumentation includes pressure cells to measure loads imposed and transferred through the platform, shape accel array and settlement plates to monitor platform settlements throughout its lifetime, during typical construction operations. The project set-up and preliminary data from the instrumented platform trial are summarised in this paper. This research will aid in future design of safe, cost effective working-platform construction.

1 INTRODUCTION / PURPOSE OF RESEARCH

Many engineers working within the construction industry would have been involved in a design and construction of working platforms. These can get as high as 1.5-2m metres of hardfill material and their cost can exceed over \$100,000. This is a significant temporary work cost and something that is often overlooked or underestimated in the bid stage of a project. The design of temporary working platforms must follow the same legislation and criteria as any other construction work designs. A number of methods exist that are currently used to design temporary working platforms (TWf, 2016). The current best practice for the design of working platforms in NZ is using the internationally accepted BRE470 (Watford, 2004) methodology which is only applicable to a specific range of site conditions. Within the construction industry there is a reputation for working platforms being over designed and over conservative.

Another complexity involved in the design of working platforms is the inclusion of geosynthetics that can stabilise or reinforce the working platform. Inclusion of these often allows a reduction in the thickness of a platform, however design methods are either limited to the manufacturer's recommendations or based on an out-of-date understanding of geosynthetics performance. Hence, again potentially generating conservative designs.

To address this industry wide issue and better understand factors affecting performance of temporary working platforms Brian Perry Civils Ltd, Geotechnical team undertook a research and development project into the optimisation of working platforms. This project consists of two stages.

1. A full scale working platform in the form of a causeway embankment was constructed. The platform is a part of a real life project with ongoing operations. This platform was constructed with instrumentation that makes it possible to monitor real time settlement and stress distribution through the platform during the construction and use of the platform.
2. The second stage involves collaboration with the University of Auckland to develop a new model for working platform design. This will be done through calibration of the numerical model, design methods and monitoring data collected.

This paper describes the project setup in detail and focuses on the geotechnical instrumentation deployed within the platform. In addition, details and challenges around acquiring consistent, reliable data are reported. The initial instrumentation data collected throughout the construction of the working platform is also presented.

This real scale monitoring experiment, which is a part of live construction project, has the potential to have a major impact on the construction industry, not only through the optimisation of working platforms designs but also through enhancing risk management due to reduction of potential platform issues. This can be achieved through an improved understanding of the factors that affect a platforms lifecycle, true stress distribution and settlement behaviour within and below the structure.

2 SITE DESCRIPTION

The full scale experiment is a part of large infrastructure upgrade North of Auckland, New Zealand. The project comprises of the construction of a new four-lane, 18km motorway. This temporary working platform has been constructed to allow the future construction of a viaduct spanning across a 330m wide existing tidal valley with soft, estuary deposits. The causeway comprising of engineered granular fill with multiple layers of geosynthetics needs to be constructed to facilitate access under the bridge to install foundations, piers and structural components. The causeway comprised of three fingers, that each service the viaduct pier locations as shown in Figure 1. The third finger shown in Figure 1 is the object of this research project.

The platform will be in place throughout the construction of the viaduct, for a duration of approximately two years. During this period, there are a number of construction operations that need to be completed using the instrumented causeway finger/ working platform. This includes the following:

- Bored piling using a 100t crawler crane;
- 100t handling service crane;
- Concrete pumps;
- General construction vehicles (including compaction equipment, excavators, truck deliveries, concrete trucks);
- Steel girder tandem lift using 2 x 250t crawler cranes lifting 90t girders (critical lift);

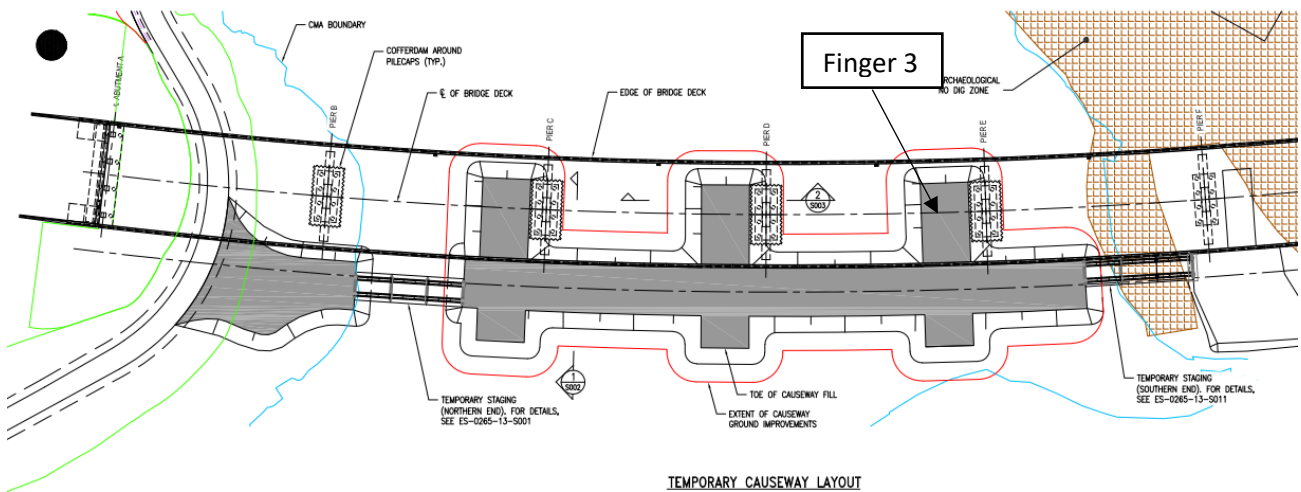
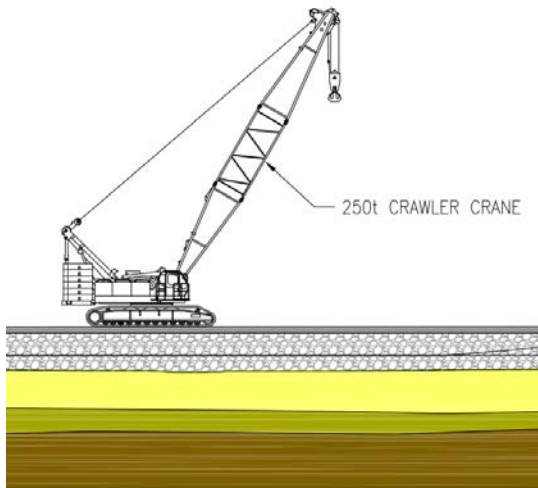


Figure 1: Site Layout

3 Geotechnical Information

The ground conditions at the viaduct location typically comprises of recent estuarine deposits (Tauranga Formation) underlain by Pakiri Formation. This information has been interpreted through the ground investigations carried out by the project team which included machine boreholes, cone penetration tests, and laboratory tests.). The ground conditions at the third finger are indicated in a geological long section presented in Figure 2.



LEGEND:

- Organic fine-grained soil, very soft (~3.5m thick)
- Inorganic fine-grained soil, stiff (~1.5m thick)
- Slightly weathered to weathered, interbedded Pakiri Formation (SPT 'N' > 50)

Figure 2: Site Ge

4 MEASURED PARAMETERS AND INSTRUMENTATION

State of the art geotechnical instrumentation measuring pressures and settlement was installed on the 14th May 2018 on the site. Figure 3 shows the layout of the instrumentation in plan and section. Table 1 presents summary and specific features of the instrumentation:

Table 1: Instrumentation Summary

Measuring gauge	Number installed	Range of operations	Specific features
Settlement plates	8	Manual survey readings	Localised monitoring
SAA	2	Sensors that can measure tilt in two directions. Automated readings that can be collected at a programmed interval.	Each cable comprises 40 settlement sensors every 0.5m
Pressure Cells	8	70kPa-20MPa. Automated readings that can be collected at a programmed interval.	Include temperature gauge but still require temperature calibration

Figure 4 shows the process of monitoring instrumentation being installation prior to coverage by the temporary platform hardfill. The figure shows settlement plates and the two SAA.

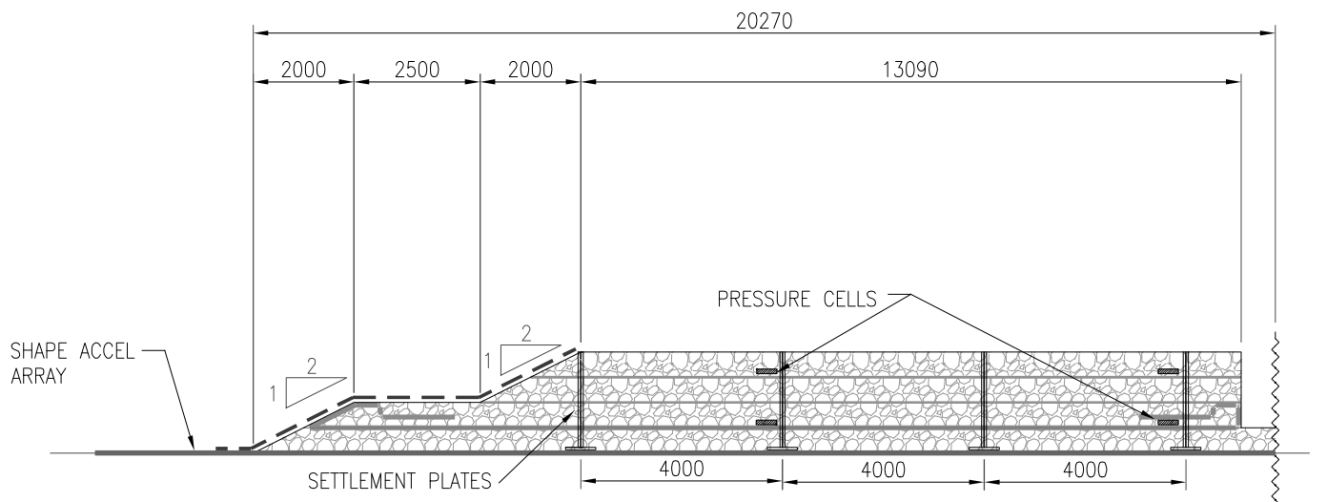
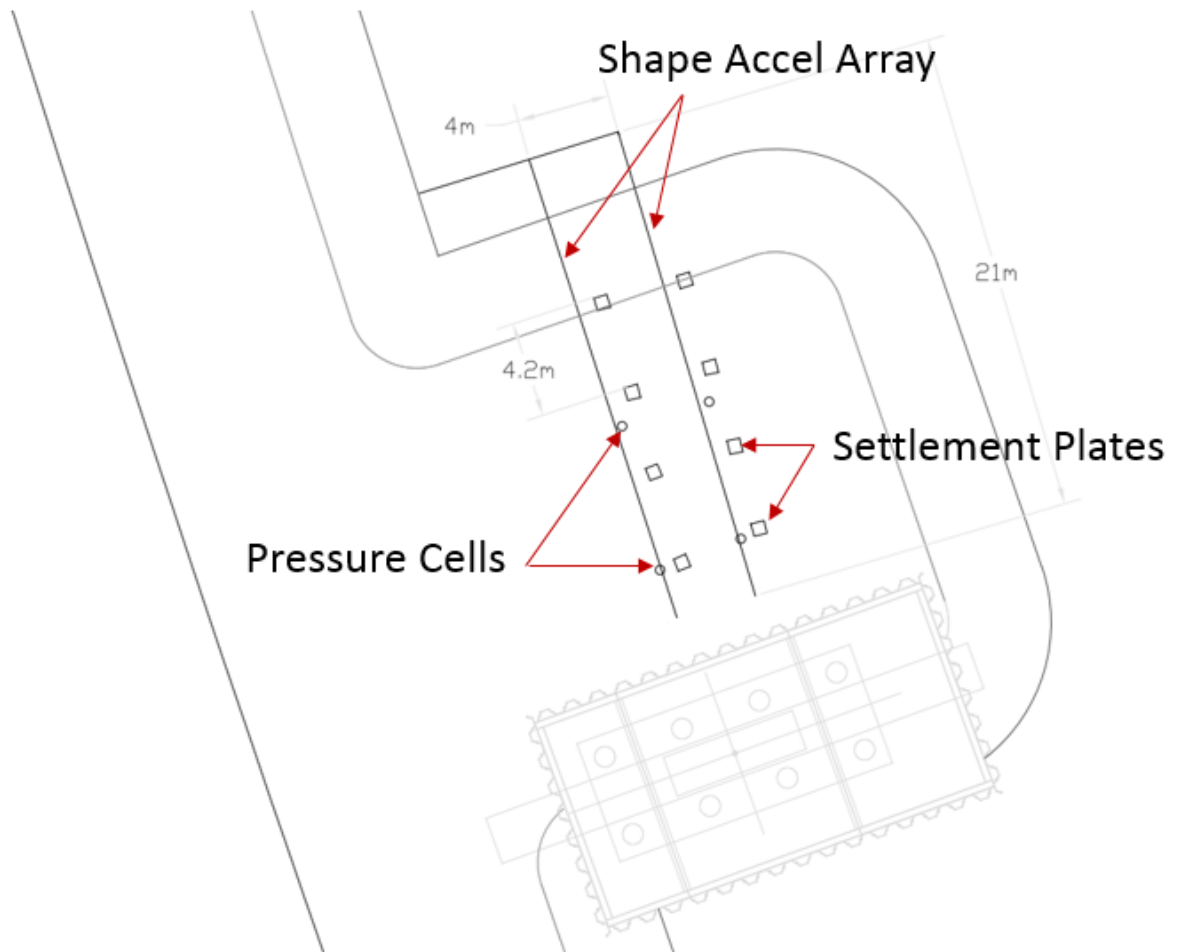


Figure 3: Layout of Instrumentation



Figure 4: SAA and Settlement Plates Installed

4.1 DISPLACEMENTS/ SETTLEMENT MONITORING

Degree of settlement is one of the most important factors that is monitored during the platform construction and during its utilisation. Therefore, two independent methods of settlement monitoring were selected in order to provide an accurate indication of the ongoing settlement and subgrade consolidation.

4.1.1 Settlement Plates

A total of 8 settlement plates were installed. These were spaced at approximately 4m intervals along the SAA at the bottom of the platform on the existing ground. Settlement plate monitors consist of a base plate with a reference extension rod that has threaded connections. The rod can be extended as the fill above the base plate is installed. The extension rod is protected inside a riser pipe. The height of the base plate is surveyed prior to placing fill and these elevation are used as the baseline readings. The elevation of the extension rod is surveyed on a regular basis to allow the settlement and consolidation of the subgrade to be measured. The main purpose of the settlement plates is to monitor overall long term consolidation settlement as well as cross check the data that is provided by the SAA. Settlement plates are a simple and low cost method for measuring settlement (Geokon, 2016). However, they only provide localised information on the settlements and require frequent visits from a surveyor to take manual readings.



Figure 5: Settlement Plates at different stages

4.1.2 Shape Accel Array

Two horizontal shape accel array (SAA) have been installed along the bottom of the platform. These are both 21m in length and spaced approximately 4m apart. Each cable comprises of 20 settlement sensors spaced every 0.5m. The purpose of the SAA is to track the settlement of the material under the platform. The SAA is made up of rigid segments that are connected by joints, the segments contain micro mechanical system (MEMS) sensors that measure tilt in each individual segment (Measureland, 2017). Using the bend angles and known segment lengths the shape of an SAA can be determined. In this case 2D data is being collected. There is one fixed end of the SAA that is attached to a settlement plate so any changes in the elevation of the fixed end can be recorded. The advantage of the SAA over the settlement plates is the increased frequency of readings along the platform profile as well as the automation of data collection.

To install the SAA, the SAA cable was threaded into PVC pipe to ensure the SAA is protected during the project life. The data is collected from the SAA and stored in a data logger, throughout the construction of the platform data has been gathered at 10 minute intervals. When specific construction tasks take place, this frequency will be increases to approximately one second intervals. This will allow the collection of real time data during an activity such as a crane lifting a girder. This will provide valuable information on the deformations occurring under the platform.



Figure 6: SAA Installation

4.2 PRESSURE

4.2.1 Pressure Cells

A total of 8 pressure cells were installed, these were Geokon vibrating wire earth pressure calls, model 4800. The location of the pressure cells is consistent with the two SAA as per Figure 3. These locations will also eventually align with where the crane tracks are positioned. Four of the pressure cells have been installed approximately 500mm below the platform surface and the other four approximately 500mm above the bottom of the platform. The pressure cells were installed by digging a shallow trench. A small grout pad was placed in the bottom of the trench for the earth pressure cell to sit on as shown in Figure 7. The pressure cell was covered with compacted hard fill and the cables from the pressure calls were run through PVC conduit and surrounded by sand to avoid damage.

The purpose of these is to calculate the pressure applied by the machinery operating but also determine the load spread through the platform. The cells are made up of two stainless steel plates that are welded together around the edge and separated by a narrow cavity filled with de-aired oil. As additional pressure is applied, the two plates squeeze together and the fluid pressure inside the cell increases. This pressure is converted into an electrical signal by a vibrating wire pressure transducer which can be transmitted in to a readout (Geokon, 2018). Data readings from the pressure cells, during the construction of the platform were collected every 10mins, similar to the SAA.



Figure 7: Pressure Cell Installation

5 DATA COLLECTED DURING PLATFORM CONSTRUCTION

All monitoring equipment has been recording data throughout the construction of the 2m thick platform. The preliminary data collected during the construction is presented in the graphs in this section. A timeline summarising the events that have taken place onsite is presented in Table 2.

Table 2: Timeline of Events

Date	Event
14/05/2018	Install monitoring equipment
15/05/2018	0.5m installed over SAA2
17/05/2018	0.5m installed over SAA1
21/05/2018	First layer of Pressure cells installed
29/05/2018	Platform filled to 1m
18/06/2018	Platform filled to 1.5m
2/07/2019	Platform filled to 2m

The total settlement up to the 15th of June 2018, from the settlement plates is displayed in Figure 8. It can be seen the general trend for all plates is very similar. However, it should be noted that this is a preliminary data that needs to be adjusted to exclude the effects of the installation process.

The two SAA profiles are shown in Figure 9. During the construction phase of the project data was collected 24 hours a day at 10 minute intervals. The profiles in Figure 9 display how extensive the data provided by the SAA is. These profiles display some areas encountered higher settlement values than others. However, excluding the two ends of the SAA the rate of settlement across the SAA profile seems to be reasonably uniform. The areas with higher settlement values are expected to be the result of aggregate deliveries and compaction equipment using certain areas for access points. Similar to the way the settlement plate data has been presented, a single node can be selected and the settlement at this node can be plotted as shown in Figure 10.

Pressure cell data from the construction phase of the platform is shown in Figure 11. Initially two of the pressure cells stayed exposed to the weather as they were not buried. During this period they were affected by temperature variations due to the expansion and contraction of the oil inside the plates. After the plates were covered these temperature fluctuations were reduced. This data needs further calibration and adjustment as the pressure readings are currently showing negative pressures which is not possible. This preliminary data shows clear increases in pressure when material is added to the platform during construction.

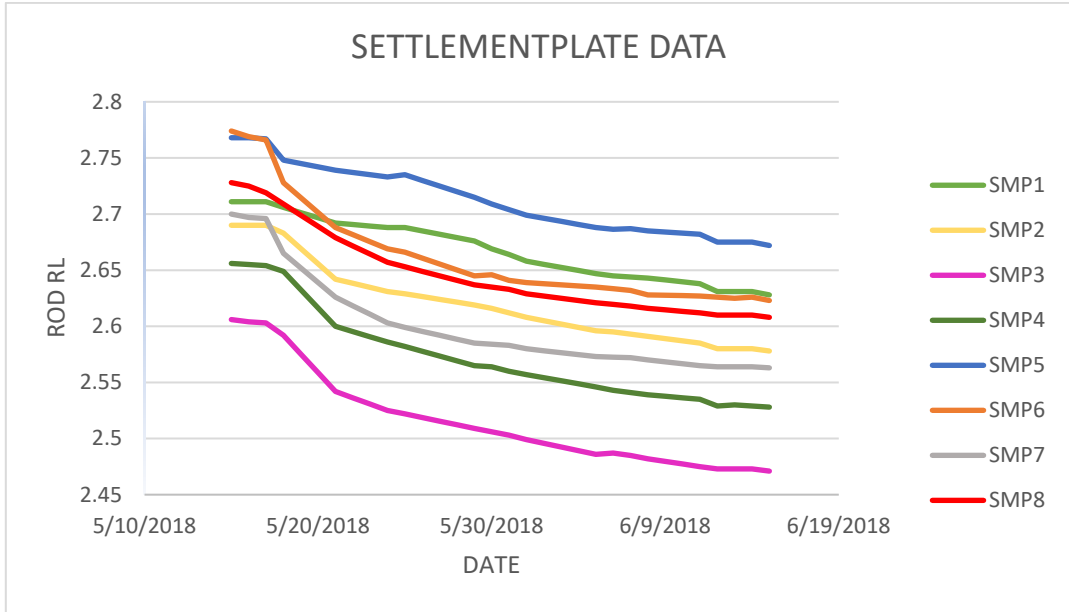


Figure 8: Settlement Plate data throughout construction

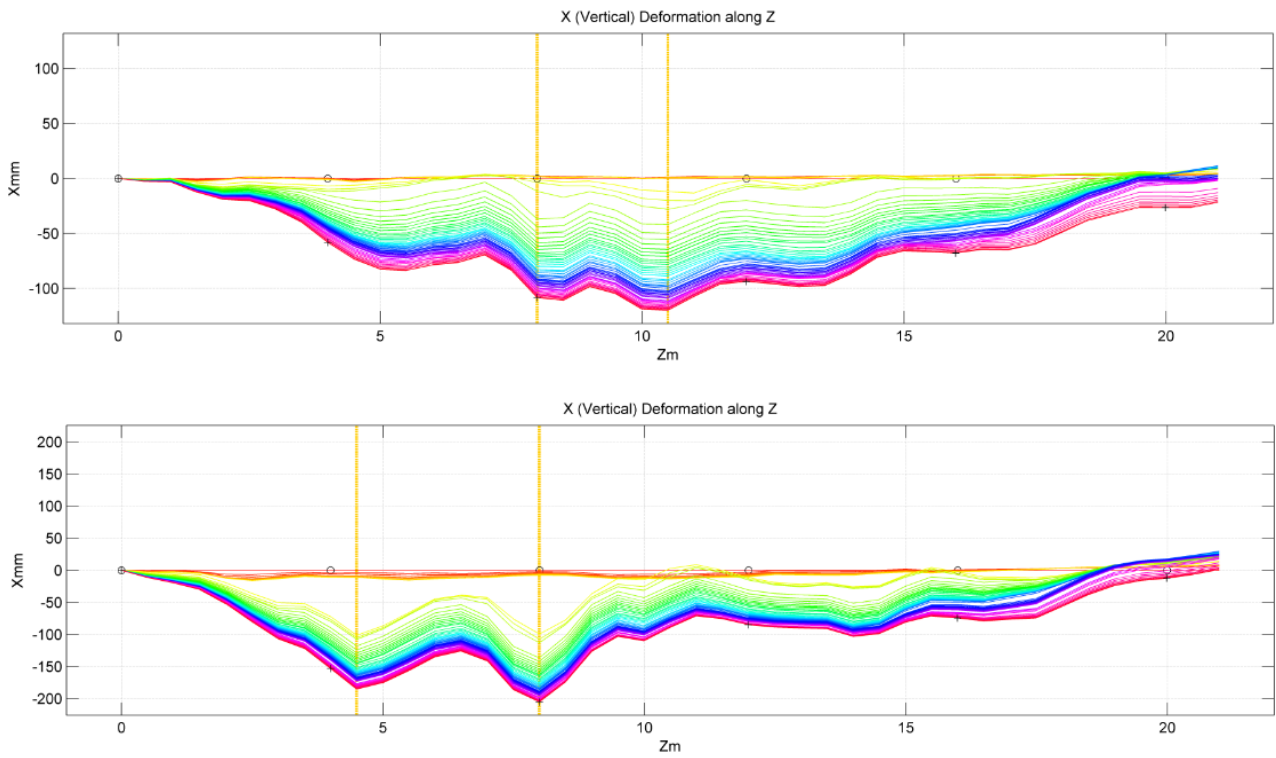


Figure 9: SAA Settlements Profile along the full SAA profile

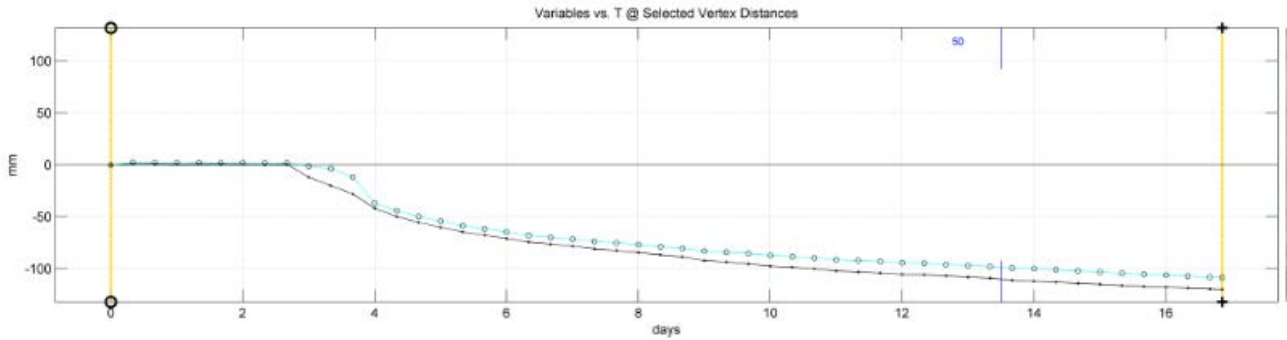


Figure 10: SAA profile Settlement at one Node

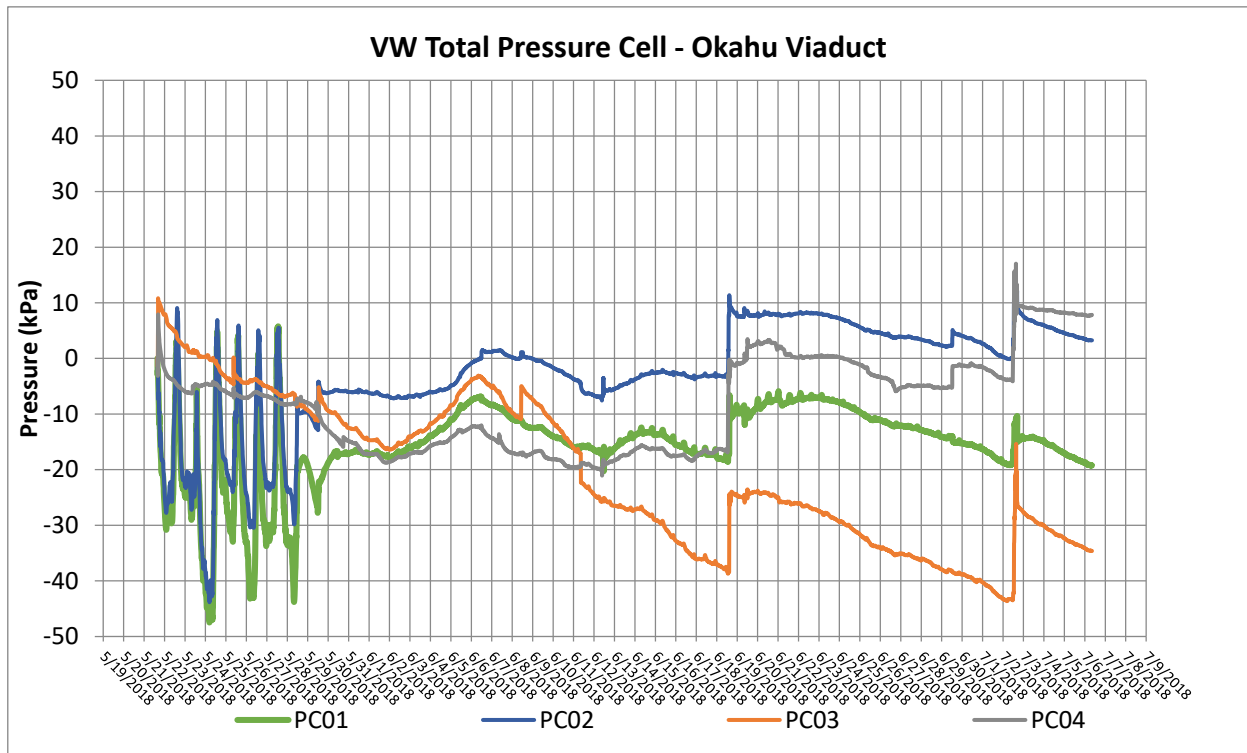


Figure 11: Pressure Cell Data

6 CONCLUSION

The overall aim of this ongoing project is to validate an advance numerical model that can be applied to accurately model the design requirements for working platforms. At this point, none of the significant construction loads have been applied to the platform. However, the foundation to collect valuable data is now in place. With all the instrumentation installed and running it is now possible to collect similar information, to that collected during the construction phase, throughout the use of the platform. By increasing the data collection interval for the pressure cells and SAA, comprehensive data can be collected showing the performance of the platform and the response to a significant crane loading.

The data collected through both the construction phase of the project, covered in this paper, and during the life of the platform can then be used to calibrate an advance model for the design of working platforms. Ideally this model will accurately represent the site behaviour of platforms under high plant loading.

Despite the cost implications associated with working platform, there has been little research into the design of working platforms. This full scale, instrumented platform research and development project has the potential to improve the design methodology currently used throughout the construction industry and provide an efficient, streamline design that results in safe cost effective working platform designs.

7 REFERENCES

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