REMOVABLE SINGLE BORE MULTIPLE ANCHORS (SBMA) - Advancements in Temporary Ground Anchor Systems

M. R Sentry[1] and D. Mothersille[2].

[1]Geotechnical Engineering, 174 Turner Street, Port Melbourne, Australia 3207; PH (+61) 3-9624-4200; FAX (+61) 3-9624-4230; email: matthew@geotech.net.au
[2]Singlebore Multiple Anchor Ltd, P.O. Box 432, Harrogate LDO, HG3 1YR, UK; PH (+44) 0-7961-134-943; email: devon.mothersille@sbmasystems.com

ABSTRACT

Successful world-wide installations and extensive research and development into a specialist ground anchor technology, the Single Bore Multiple Anchor (SBMA) system, over the last two decades, has made available ground anchor technology which allow a reduction in cost per tonne of retention force for anchors in soils and weak rocks. In addition, there is the availability of an extension to the technology which on completion of the temporary works service life allows the *complete* removal of the entire tendon strand from the ground. This feature has made the use of temporary removable anchors more attractive to the owners of adjacent properties, municipalities and highway authorities since future construction in the vicinity of the anchor boreholes unobstructed by the presence of steel prestressing strand. The paper presents an overview of the patented removable Single Bore Multiple Anchor (SBMA) system along with supporting invaluable test data obtained from the first application of the system in Australia. The test data presented compares removable SBMA system performance with conventional temporary anchor systems and summaries the efficiency of tendon strand removal.

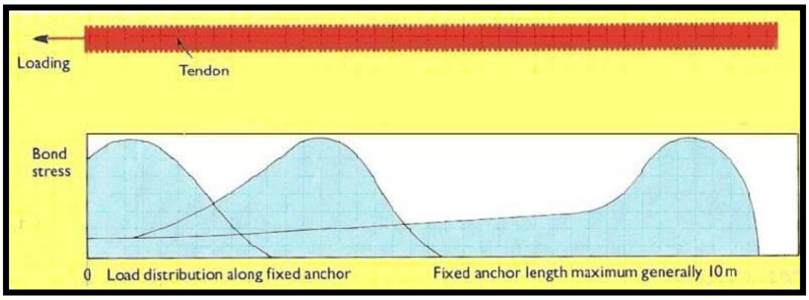
Keywords: SBMA, anchor, removable, temporary anchor.

1 INTRODUCTION

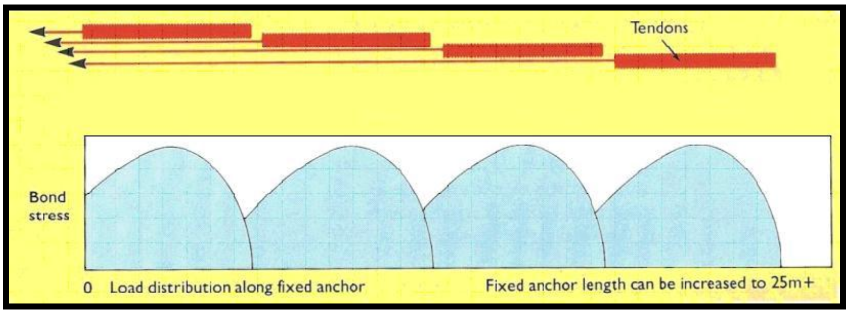
As society expands and develops, there is an increasing need to investigate more cost effective and environmentally acceptable construction methods. Ground environments, where temporary support into weak strata conventionally required large, cumbersome and costly internal propping systems, inevitably restricted space and as a consequence inhibited the construction cycle. In such ground conditions, conventional temporary anchor systems were unable to mobilise adequate bond-stress at the ground-grout interface and the provision of long fixed anchors has been shown to be highly inefficient.

The elastic behaviour of grouted soil around an anchor tendon is unlikely to be compatible with the elasticity of the tendon and enable uniform distribution of the applied loads along the fixed anchor.. It is widely acknowledged that progressive de-bonding of the anchor system is a result of non-uniform bond stress distribution along the fixed anchor, see Figures 1a and 1b (Barley, 1995, 1997 and Mothersille et, al. 2011). .

The decommissioning of conventional temporary anchor systems is generally accomplished by de-stressing of the anchor. This is commonly achieved by the removal of the anchor block and wedges by means of cutting or heating of the tensioned strand at the base of the anchor block. The major shortcoming with such a system is that the distressed steel tendons are left within the boreholes, often located under municipal, highway authority or adjacent property owners land. The use of a removable temporary anchor system has, therefore, become more appealing to owners of adjacent properties, municipalities and highway authorities as they seek to reduce the risk obstruction or damage to future works.



(a)



(b)

Figure 1: Principals of the SBMA System (a) progressive debonding effect on anchors; (b) SBMA system

2 REMOVABLE SBMA

The removable SBMA provides a means for structural support through a series of unit anchors within the one borehole. The number of unit anchors required is dependent on the ground conditions and working load requirements.

The system utilises a series of fully greased and sheathed strands installed within the same borehole to mobilise bond-stress distribution over a larger area (Figure 2). Bond stresses for each unit is generated by the applied force action on the grouted saddle. Within a unit anchor the greased and sheathed steel strand is looped around a saddle at the distal end (Figure 3). The provision of fully greased and sheathed strand facilitates easy removal once the system is de-stressed. After installation and grouting, both ends of the looped strand are simultaneously stressed and locked off using an anchor block and wedge arrangement. Subsequent removal of the strand from the borehole is achieved by applying a force to one end of the looped tendon (Figure 4). This action will pull the looped strand around the saddle (located at the anchor distal end) and out of the borehole, leaving only the sheathing, grout and saddle remaining.

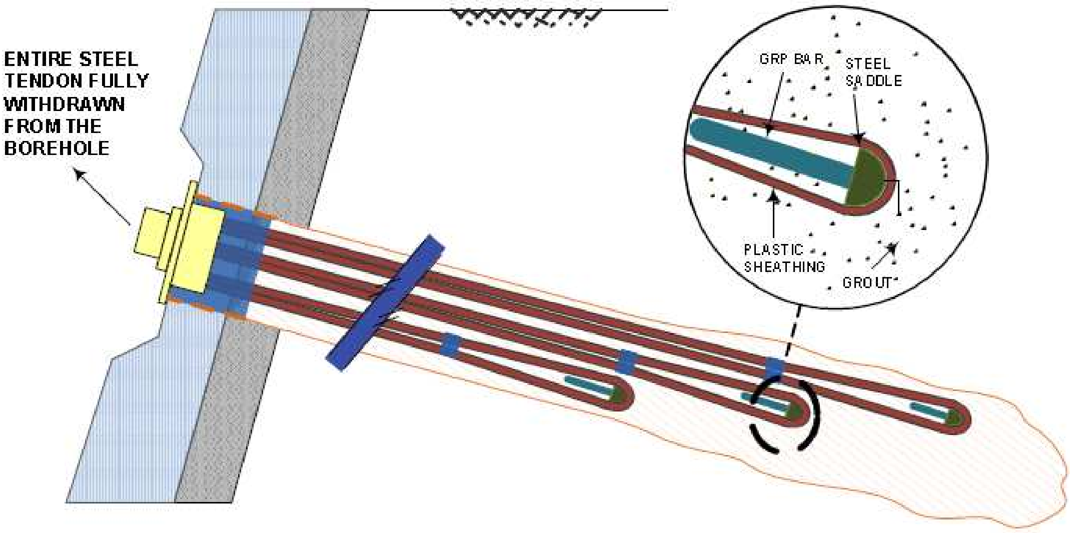


Figure 2: Removable SBMA System

Figure 3: Saddle arrangement for Removable SBMA systems

Figure 4: Removal of strand

3 REMOVABLE SBMA TEST CASE - AUSTRALIA

A series of test removable SBMA's were installed as temporary supports for deep excavation piles in the North Western suburbs of Melbourne. The project required 85 two strand temporary ground anchors with a design working load of 200kN to support a 9.0m deep excavation into slightly weathered basalt during construction of an apartment block. An opportunity was provided to install a series of test removable anchors into this project. The purpose of the test programme was to confirm that the fabrication, transport and installation process did not damage in anyway the integrity of the removable anchor and to assess the performance of removable anchor and verify removability of the looped strands from within the borehole. The test anchors were installed adjacent to conventional anchors. Strand properties are summarised in Table 1. The parameters of these anchors is summarised in Table 2.

Table 1: Steel Strand Properties

Property	Unit	Steel Strand
Diameter	mm	15.2
Effective Cross Section Area	mm^2	143
Linear Weight	Kg/m	1125
Tensile Strength	MPa	1750
Elastic Modulus	GPa	195

Table 2: Removable SBMA Test Case Parameters

No. Tendons units	No. Anchors	No. Anchor Units	Design Working Load (DWL) (kN)	Anchor Length (m)	Anchor Bond Length (m)
Conventional Temporary Anchors	85	1	200	9	3
Removable SBMA Anchors	3	1	200	12	N/A

Fabrication of the removable anchors was carried out under factory controlled conditions at Geotechnical Engineering's anchoring workshop. Factory fabrication of the removable anchors ensured that full quality control could be administered in a controlled, clean environment, where attention to critical fabrication components was achieved successfully. Once fabricated, anchors were transported to site on a flat bed truck. Access on site enabled the removal of the anchor directly from the truck and into the borehole. As anchors were only 12 meters, there were no complications with transport. For larger anchors, a transport frame will need to be fabricated to ensure anchor integrity.

Boreholes were drilled using the same technique for all anchors involved in this test case. Drilling was carried out using a hydraulic top-hammer drill rig. Anchors were installed and grouted using a 0.45:1 (water:cement) grout mix. Grout was mixed in a high shear colloidal grout mixer to ensure full strength of grout was achieved. Figure 5 provides an overview of the fabrication, location and installation of the removable anchors.

(a) (b) (c)

Figure 5: Test case removable anchors (a): Fabrication; (b) location; (c) installation

Each removable anchor was uniformly loaded to 1.5 times the design working load (DWL) and sustained for 15 minutes. Proof load testing was carried out in accordance with AS4678-2002. Each anchor was then locked of at the DWL. Load-extension data for the test anchors were recorded (Figure 6).

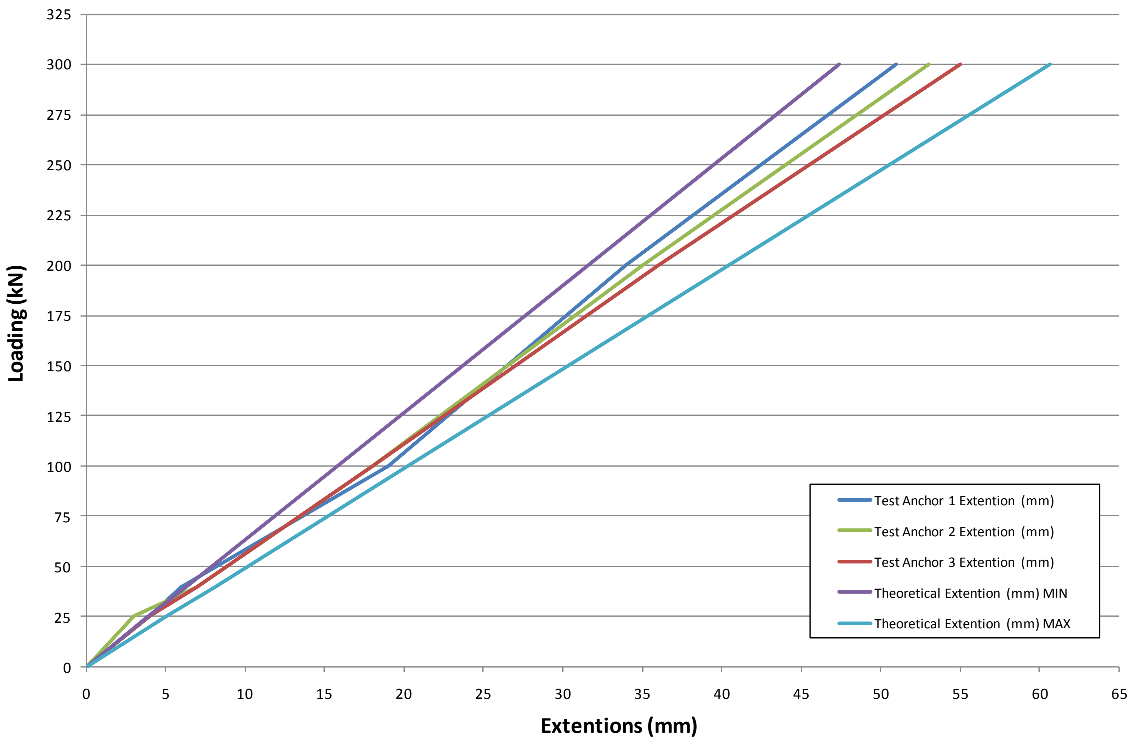


Figure 6: Load v extension results for removable anchors

Upon decommissioning of the temporary and removal anchors, lift-off tests were carried out on each anchor to verify anchor performance (Table 3). The results indicate that the removable anchors perform as efficiently as conventional temporary anchors when exposed under the same working conditions. A 2% load loss was recorded after 9 months of service.

Table 3: Lift-Off Performance Test

	Temp Anchor 1	Temp Anchor 1	Temp Anchor 1	Removable Anchor 1	Removable Anchor 1	Removable Anchor 1
Lift-off Load (kN)	194	196	186	196	197	197
% of DWL	97%	98%	93%	98%	98.5%	98.5%

Each removable anchor was then distressed without damaging the strand. Once distressed, the tendons were removed by a combination of hydraulic jacking (initial stages) (Figure 7) and electronic winching (mobile plant) (Figure 8).

During the removal of the tendon, it was observed that the initial force required to initial the tendon was in the order of 80-90kN. Once initiated, an applied force of 30-40kN was required to extract the tendon from the hole. It was observed that a force of 90-100kN was required to pull the last section of tendon around the saddle. Once the tendon was completely around the tendon an applied force in the order of 50kN was required to extract the tendon. The reason for this increase is due to the strand coiling effect as a result of being pulled through the saddle at the anchors distal end.

Figure 7: Hydraulic jacking of removable tendon

Figure 8: Removal of tendon using winch

In order to minimise a whipping/springing effect of the tendon as it existed the borehole, the tendon was progressively extracted in two to three meter sections and the extracted section cut with a grinder. This method ensured safety of plant operator and surrounding work environment. The lengths of extension can be adjusted to suit on site space availability and recycling constraints. As the tendon was progressively cut during extraction it was stock-piled for recycling.

4 CONCLUSION

The need for a temporary anchor system that is capable of working in a range of ground strata is becoming more desirable throughout Australia and internationally. The developments of the removable SBMA system enables a series of unit anchors to be installed within a single borehole which can be removed at the completion of the works. The ability to remove the tendon from the borehole provides piece of mind to clients, asset owner and owners of adjacent properties.

Removable anchor test case conducted in Melbourne identified that a sound fabrication assembly system is paramount to the quality and integrity of the removable anchor; the removable anchors perform as well as conventional ground anchor systems; and the removal of the anchor tendons is possible through the use of skilled personnel, hydraulic jacks and winches. The removable anchor system provides an environmentally friendly means to temporary anchor construction whereby the distressed steel stranded tendons can now be removed and recycled.

5 ACKNOWLEDGEMENTS

The authors would like to acknowledge the support from Hamilton Marino Builders for providing a field location for the test case anchors.

REFERENCES

Barley, A.D (1995) "Theory and Practice of the Single Bore Multiple Anchor System". International Symposium on "Anchors in Theory and Practice", Saltzburg, Austria.

Barley, A.D (1997) “The Single Bore Multiple Anchor System” ICE Conference, Ground Anchorages and Anchored Structures, London, UK

Mothersille, D., Bayer, A.O., Okumuosoglu, B (2011) “The performance of Single Bore Multiple Anchor trials installed in mixed Moscow soil. Proceedings of Road Construction Conference, Penza, Russia