Single Bore Multiple Anchor Systems (SBMAs) in Challenging and Variable Ground Conditions

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ABSTRACT Single bore multiple anchors (SMBAs) are ground anchors that incorporate multiple individual unit tendons of varying lengths, which are installed within a single borehole. Decades of research and practical applications have demonstrated that this configuration facilitates greater efficiency of load transfer to the surrounding ground. Unlike conventional ground anchors, especially in heterogeneous and variable ground conditions, the design of SBMAs can be optimized because the bond length of an individual unit anchor can be designed individually, thereby utilizing and maximizing the inherent strength of the ground. Historically, SBMAs have been used for both permanent and temporary earth support systems, and, where project circumstances dictated, SBMAs have been installed with removable tendons, which permitted the complete removal of the prestressing steel strand (at the end of the anchor's design service life). The installation of SBMAs is congruent with that of traditional ground anchors, and the testing protocol is similar regardless of anchor type. However, unlike conventional ground anchors, the stressing of SBMAs can require a different set up, whereby separate hydraulic jacks are hydraulically synchronized to stress each individual tendon simultaneously so that each unit anchor receives the same load. This paper will provide a general overview of the design, installation, and testing of permanent, temporary, and removable SBMAs along with the applicability for their use and the benefits afforded from using this type of anchoring system. The paper will also present and discuss applications in different ground conditions and test results via mini case histories where SBMAs have been implemented worldwide. The use of specially developed tablet-based software that allows real-time analysis and data management of the anchor testing process will also be presented with reference to SBMAs. Finally, it will be shown that, depending on the ground conditions and project requirements, it is possible that SBMAs can double the capacity of conventional anchors, thereby generating substantial savings in program time and cost.

Keywords: anchors, single bore, multiple anchor, theory, design, case history

INTRODUCTION

For more than three decades, the SBMA system has been used successfully worldwide for anchoring applications in soils and in weak rocks. The system is a ground anchor solution that is applicable to permanent in addition to temporary anchor installations. By effectively distributing the load along the fixed length portion of the anchor, SBMAs efficiently mobilize and maximize ground strength and, in appropriate ground conditions, can double the capacity provided by conventional anchors.

Barley (1997) commented that a conventional grouted anchor with a 10 m (33 ft) long fixed length (i.e., bond length) in soil or rock will, at the test load, need to extend some 30 mm (1.2 in) at the proximal end of the fixed length before any load will be transferred to the distal end of the tendon. Since the elastic behavior of the tendon is dissimilar to that of the grouted soil around it, the resulting differential strains induced during loading cause debonding at the weakest interface, which, in soil and weak rocks, tends to be along the ground-to-grout interface. As the anchor approaches the geotechnical strength limit state (i.e., ultimate ground-to-grout resistance), a highly non-linear profile of bond stress results (Figure 1). For clarity, *resistance* commonly refers to the properties of the ground/grout interface, whereas *capacity* generally refers to the strength properties of the tendon.

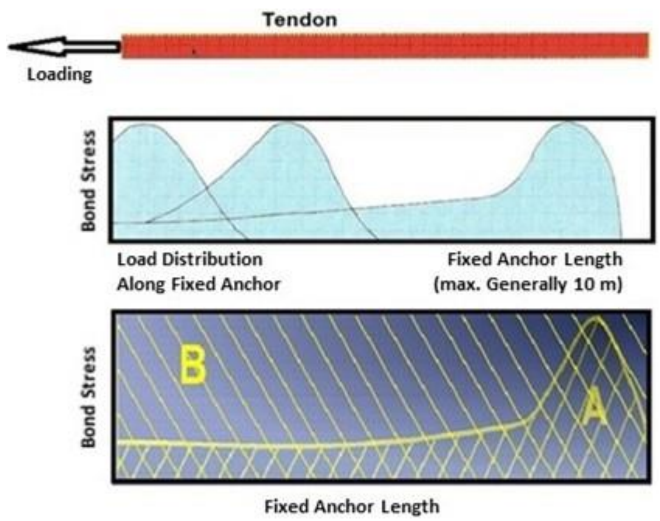


Figure 1. Progressive debonding along a conventional fixed anchor length

Progressive debonding, as the phenomenon is commonly referred, generally results in an inefficient use of the in-situ ground-to-grout bond strength. Under these circumstances as the tendon undergoes elongational deformation, more of the resistance towards the distal end of the fixed length of the anchor is being utilized since the peak bond strength toward the proximal end has been exceeded (Figure 2a). That is, during elongational deformation, the available resistance increases to a peak state; however, once the peak bond strength has been exceeded, the available resistance reduces to a softened strength state and then to a residual strength state with continued deformation. Conversely, SBMAs provide a more optimized anchor system that can transfer the applied loading simultaneously to multiple separate short unit lengths within the fixed length of the anchor with significantly reduced progressive debonding. By doing so, the in-situ ground-to-grout bond strength is mobilized efficiently, resulting in a considerable increase in the capacity of the anchor (Figure 2b).

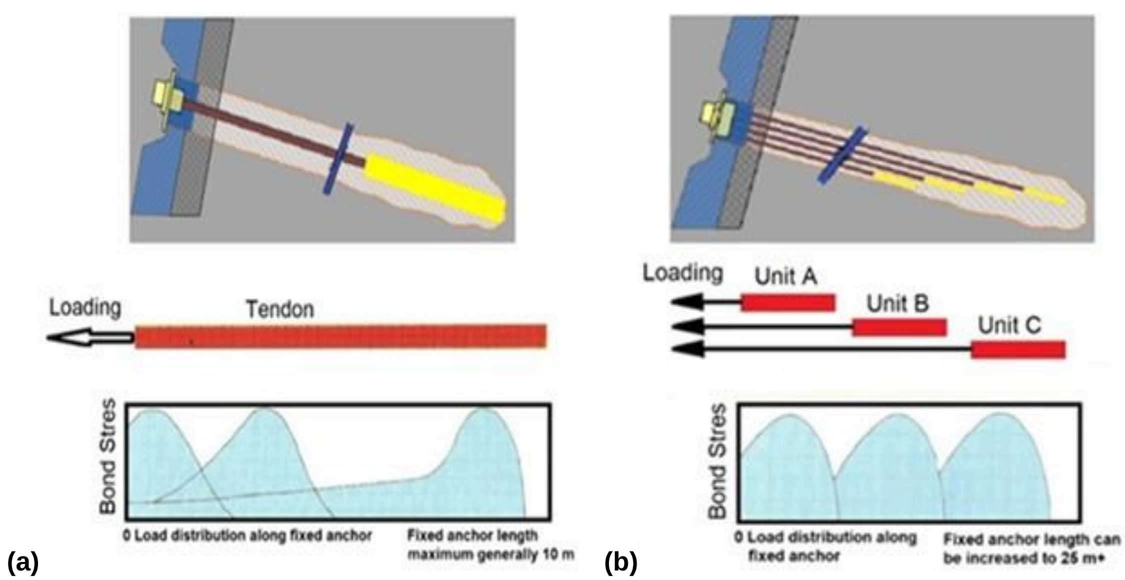


Figure 2. Load distribution in (a) conventional anchors and (b) SBMAs

SBMA systems fall into three basic categories: temporary, permanent, and removable systems. The temporary SBMA system is applicable to projects where the design service life is typically no more than about 2 years. Under normal circumstances (e.g., no aggressive ground conditions), short term protection of the anchor tendon is provided only by the cement grout encapsulating the tendon. The permanent

SBMA system comprises a full double corrosion protection in compliance with international codes of practices and will satisfy the design life of the structure typically up to about 120 years. It is noteworthy that should aggressive ground conditions be encountered, and/or the consequences of failure be categorized as high, similar corrosion protection as for permanent anchors should be implemented for temporary anchor systems. Aggressive ground conditions (i.e., potentially corrosive) are denoted or classified according to the electrochemical properties (i.e., pH [acidic or alkaline], salt content, and resistivity) of the soil, presence or potential of stray electrical currents, type of soil (e.g., organic and calcareous), and presence of debris or industrial waste (e.g., fly ash, cinder, and slag). The SBMA removable anchor is a technology that permits the prestressing strand tendon to be fully removed from the borehole at the end of its design service life. Examples of each system will be presented in the Case History section below.

DESIGN OF SBMAs

The design principles associated with the SBMA system are well documented in the literature, and its load transfer mechanism is recognized by major international codes of practice including in the British Code of Practice for Ground Anchors, BS 8081:1989/2015 (BSI, 1989 and BSI, 2015); European Standard for the Execution of Special Geotechnical Works – Ground Anchors, EN 1537:2013 (BSI, 2013); PTI Recommendations for Prestressed Rock and Soil Anchors, PTI DC35.1-14 (PTI, 2014); and RTA QA Specification R56, Ground Anchors (RTA, 2009).

Ostermeyer and Barley (2003) provide a detailed discussion of the process for the design of SBMAs, and the basic principles are similar to the design of conventional anchors (Eq. 1) with the exception that an efficiency factor (f_{eff}) is introduced in the equation to compute the ultimate anchor load (Eq. 2). The efficiency factor accounts for the non-linear bond stress profile already described (Figure 2).

$$T_{f\_conv} = \pi \cdot d \cdot L \cdot \tau_{ult} \tag{1}$$

$$T_{f\_SBMA} = \pi \cdot d \cdot L \cdot \tau_{ult} \cdot f_{eff} \tag{2}$$

where, T_{f_conv} is the ultimate capacity of a conventional anchor; T_{f_SBMA} is the ultimate capacity of a unit anchor; d is the diameter of the borehole; L is the fixed length of a unit anchor; and τ_{ult} is the ultimate ground-to-grout bond stress.

Based on the back-analysis of multiple anchors, each with a different fixed length, that were installed in mixed soils and tested to failure, f_{eff} was calculated from the ratio of the actual bond stress to the idealized bond stress area (Area A divided by Area B in Figure 1). Each computed ratio was plotted versus its respective fixed length (where L is in meters), as shown by the data points in Figure 3. A relationship for the efficiency factor with respect to fixed length was established using curve fitting (Eq. 3). The fixed length of conventional ground anchors ranges considerably (L = 6 to 15 m [20 to 50 ft] or longer) depending on the ground conditions and design loading; however, the fixed lengths of the unit anchors are consistently less than those for conventional anchors and typically ranges from 2.5 to 4.5 m (8 to 15 ft). As an example, the efficiency factor ranges from 0.34 to 0.58 for conventional anchors (with L = 6 to 15 m) and ranges from 0.95 to 0.68 for SBMAs (with L = 2.5 to 4.5 m). Moreover, by exploiting the fact that SBMAs can accommodate greater loads than conventional anchors, designers can reduce the overall quantity of anchors required to support the structure.

$$f_{eff} = 1.6 \cdot L^{-0.57} \tag{3}$$

The SBMA system can accommodate variable ground conditions directly and simply by adjusting the fixed lengths of the unit anchors based on the bond strength available. The individual fixed lengths can be designed

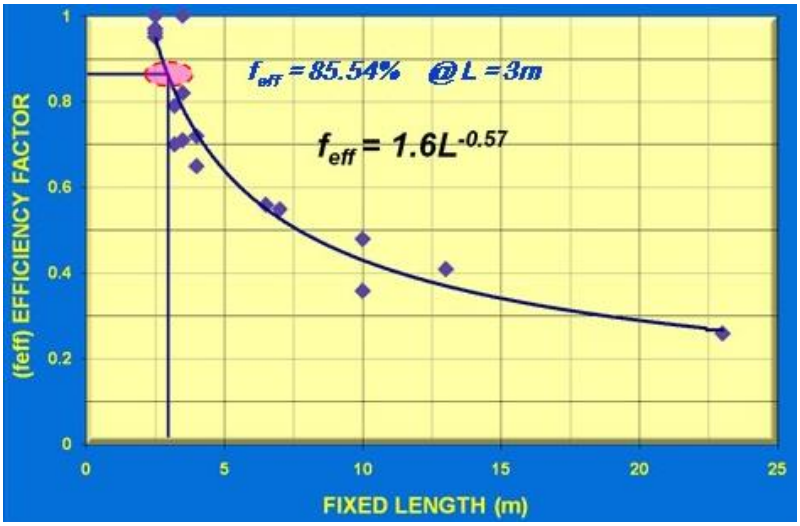


Figure 3. Efficiency factor versus anchor's fixed length (after Barley, 1997)

for ground conditions exhibiting a decrease in strength with depth, for strength varying throughout the fixed length, or for very weak bands intermixed within the deposit at irregular depths. In the latter case, the number of unit anchors is designed to allow for a potential failure of one or two unit anchors while ensuring the remaining (intact) unit anchors still safely sustain the total anchor working load (for an appropriate factor of safety or resistance factor). Furthermore, for the SBMA system, there is no theoretical limit to the total (or overall) fixed length, whereas there is little or no practical increase in load capacity for conventional anchors with fixed lengths greater than about 10 m (33 ft).

In the case of non-homogenous soil conditions throughout the fixed length, each unit fixed length can be designed for the appropriate condition and available strength. If the soil is weaker within the upper portion of the fixed length, then the proximal unit anchors will have longer unit fixed lengths compared to those at greater depth. Regardless of the unit length, equal load is applied to each unit anchor such that each unit anchor is mobilizing the same percentage of the ultimate ground-to-grout bond capacity (or, in other words, each failure would occur simultaneously). However, if the unit anchors are founded in soil conditions exhibiting different creep characteristics, the unit fixed lengths would be designed such that each unit anchor design would comply with the appropriate creep criterion in its particular service condition.

CONSTRUCTION CONSIDERATIONS

The construction and installation of SBMAs follows the general methodologies adopted in most conventional grouted anchor construction (i.e., tendon fabrication, drilling, installation, and grouting). By doubling the loads that could be applied to an SBMA, the overall quantity of anchors required for a particular structure could effectively be reduced by 50%. Such reductions in the quantity of anchors required generate significant savings in project time and costs by reducing the quantity of drilling rig set ups, drilled holes, and stressing operations.

In general, SBMAs use essentially the same overall drilled length as conventional anchors, but the composition is significantly different (i.e., about 50% longer fixed lengths per anchor but only about 67% of the total quantity of SBMAs as compared to conventional anchors). That is, irrespective of the type of anchor - conventional or SBMA, the free length (i.e., unbonded zone) is the same because this length is based on the retained height of the wall and/or the geometry of the unstable soil/rock mass. However, the arrangement and length of the fixed length (i.e., bond zone) for SBMAs is significantly different from conventional anchors (Figure 2), which results in fewer and longer SBMAs compared to more and shorter conventional anchors. Ultimately, because the goal of the SBMA design is to utilize the resistance afforded more efficiently, the overall drilled lengths are effectively similar but the quantity of SBMAs installed is less than for conventional anchors. In addition, there are greater safeguards being utilized with

SBMAs such that properly designed and well-constructed, high load SBMAs do not fail (i.e., no remedial work or specialty contractor-induced delays) even in the weakest of materials because more unit lengths can be added, as appropriate, to subsequent anchors.

The positive implications to project time and costs cannot be over-emphasized. Furthermore, whether for multiple level anchored deep basements, anchors holding down a dock floor, anchored slopes or diaphragm walls, a SBMA's high capacity can reduce the quantity of anchors, which correlates to fewer rows of anchors and/or greater spacing between anchors. Where permanent anchors are required and high capacity SBMAs can reduce the quantity of anchors, prefabricated double corrosion protected tendons offer a major advantage with respect to durability.

SBMA TESTING

Similar to all grouted anchor systems, testing of SBMAs by means of a direct tension test is a mandatory requirement, and applies to temporary, permanent, and removable SBMA systems. As described above, the systems involve the installation of multiple unit anchors into a single borehole, whereby each unit anchor has its own individual tendon, its own unit fixed length of borehole, and is loaded with its own unit stressing jack. The loading of all of the unit anchors is performed simultaneously by using multiple hydraulically synchronized jacks, which ensures that the load in each unit anchor is always identical to the others (Figure 4). That is, each unit anchor has its own hydraulic jack and each jack imparts the same load on each unit anchor; however, ram extensions differ due to different free length of each tendon element.

Under appropriate circumstances, recent developments have allowed a single jack to be employed to stress all of the SBMA tendons without overstressing any of the tendon elements during simultaneous tensile loading (Figure 5). Undoubtedly, this innovation clearly saves a considerable amount time since only one set of data for the load-extension response needs to be recorded.

(a) (b)

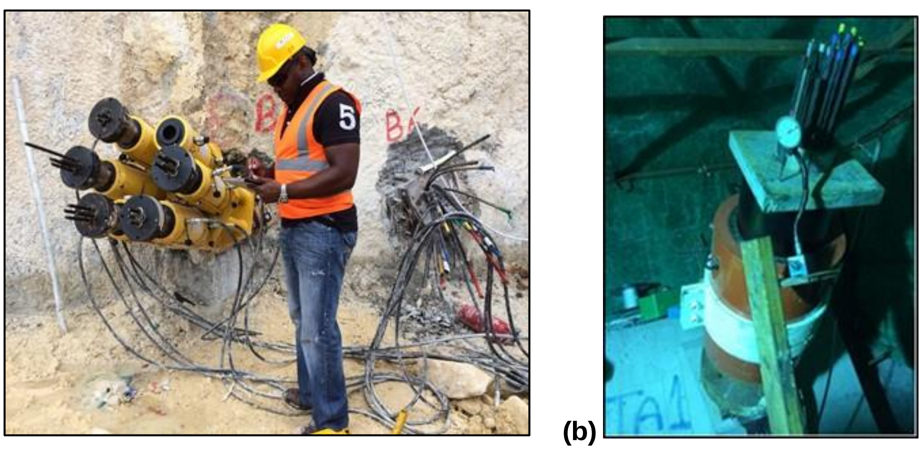


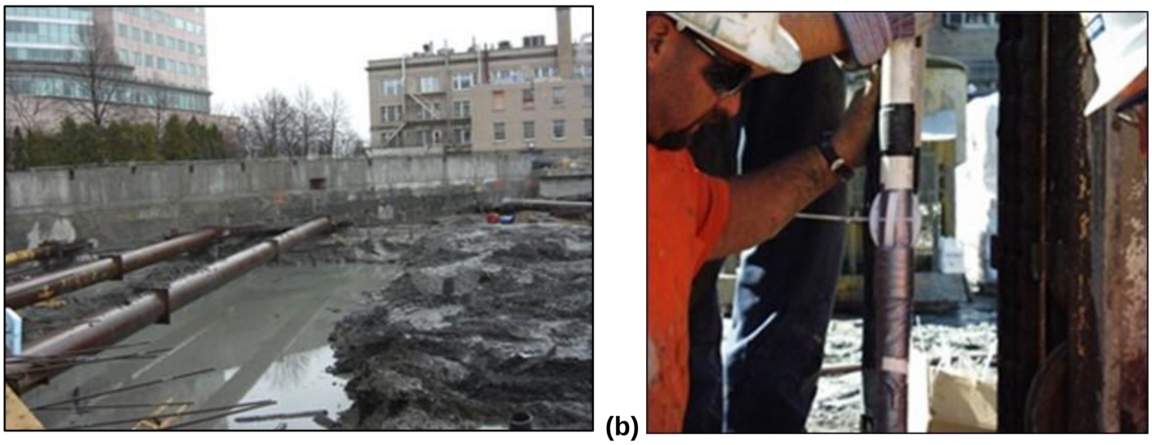
Figure 4. Testing of SBMA anchors: (a) in weak limestone using multiple jacks (Doha metro, Qatar), and (b) a single hollow ram jack simultaneously stresses a 3-unit system (Izmir, Turkey)

CASE HISTORIES

Temporary SBMAs in an Anchored Diaphragm Wall - Boston, Mass., USA

The construction of deep basement structures in Boston Clay demanded the use of innovative techniques to provide temporary support to a diaphragm wall in a notoriously weak material, which had SPT N-values between 2 and 7 blows/0.3 m (blows/ft) (Figure 5a). The use of conventional ground anchors imposed serious project restraints by the quantity of anchors required. Therefore, a proposed alternative solution, which incorporated the use of SBMAs, was considered and subsequently implemented.

In August 2007, a series of field trials were performed using SBMAs in the soft Boston Clay located at the site for the construction of the new for the construction of the MIT Management Building. The objective of this test program was to ascertain the ultimate ground-to-grout bond stresses that could be achieved at the different target anchor depths to confirm the geotechnical parameters that could be used for the design of the production anchors. Various designs for the test anchors were adopted but generally consisted of up to four unit anchors, each with a length of about 3 m (10 ft) and with between 2 and 4 15.2 mm (0.6 in) diameter 'noded' strands per unit anchor. A noded strand is also known as "bird caging," which refers to a process by which the strand wires are locally separated to enhance bond. The nature of the soft ground also necessitated the use of sophisticated secondary post-grouting techniques in the fixed anchor zone in conjunction with a double inflatable packer to maximize the capacity of the unit anchors (Figure 5b).



(a) (b)

Figure 5. Photographs of (a) the excavation site, and (b) the installation of a post-grouting tube that was used with a double inflatable packer for secondary grouting of the fixed anchor zone

The carefully supervised work successfully demonstrated the SBMAs with three unit anchors could support test loads of up to 1,200 kN (270 kip), which exceeded the capacity, by as much as 50%, achieved by conventional anchor systems. Furthermore, the addition of more unit anchors can achieve a proportional increase in the load that could be supported; that is, the use of six unit anchors would provide double the capacity provided by three unit anchors (i.e., a capacity of at least 2,400 kN (540 kip)).

During the incremental loading of the individual unit anchors, simultaneous plotting and analysis of the load-extension data was performed to facilitate an immediate assessment of the behavior of the fixed anchor and apparent free tendon lengths. The results from this work were then used to optimize the design of the production anchors. The increased loads generated by the SBMAs reduced the quantity of the anchor holes drilled and, correspondingly, the project time required for the construction of the anchors.

Temporary SBMAs in an Anchored Diaphragm Wall – Moscow, Russia

Mothersille et al (2015) reported on the testing program and installation of approximately 3,600 SBMAs to support a diaphragm wall in the highly heterogeneous soil conditions for the pedestrian-oriented, mixed-use Kuntsevo Plaza development in the Kuntsevo district of southwestern Moscow, Russia, which was the first project in Russia to utilize the SBMA technology. The challenging variable geology consisted low strength clays, sands, and sandy silts with lenses of gravel and fluvio-glacial deposits. The depth to the groundwater table ranged from about 3 to 9.5 m (10 to 31 ft), and artesian conditions were encountered deeper in the deposit in the fluvio-glacial and Lower Cretaceous sands. The anchored diaphragm wall structure was about 650 m (2,135 ft) in length along the perimeter, about 800 mm (32 in) in thickness, and was embedded to depths varying from 38 to 45 m (125 to 150 ft).

The specified design working load for each of the anchors was 600 kN (135 kip), which could not be achieved with conventional anchors due to unacceptable creep displacements. To determine the ultimate ground-to-grout bond stresses (i.e., at geotechnical failure), conventional tremie grouted anchors with a single 8 m (26 ft) long bond length, borehole diameters of either 150 or 178 mm (6 or 7 in), were installed vertically to depths between about 18 and 27 m (60 and 90 ft) into the two distinct founding layers. For pre-production or verification testing (i.e., trial anchors), it is common to use vertically installed elements to isolate the bond zone within the layer(s) of interest; moreover, there is no practical opportunity (trial anchors installed prior to the wall) or benefit to installing sub-horizontal anchors. The ultimate test load sustained was about 450 kN (101 kip), at which point the anchor exhibited continuous upward displacement. The back-calculated ground-to-grout bond stresses were approximately 175 kPa (25 psi) in the upper clays and 195 kPa (28 psi) in the lower sand layers.

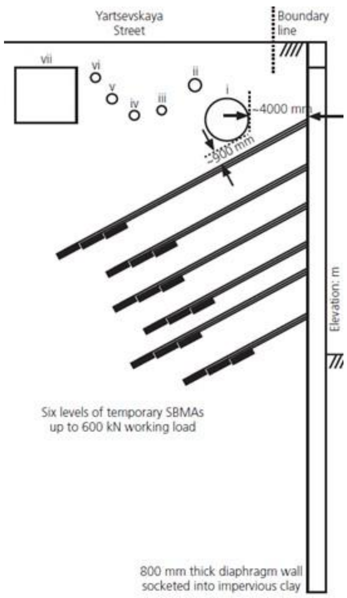
Given the sensitivity of adjacent understructures and services, an extensive testing program was performed to determine the feasibility of and design parameters for the SBMA technology, to evaluate enhanced anchor construction techniques (i.e. end-of-casing grouting in the granular soils and post-grouting in the cohesive soils), and to observe the performance data of the ground anchors with respect to limiting wall movements. The test results indicated that the maximum working loads ranged from about 580 to 780 kN (130 to 175 kip), which were greater than the maximum design load of 532 kN (120 kip). It is important to note that the ultimate bond stresses that could be achieved are a function of both the technique being utilized and the contractor's construction methodology and quality.

Using the determined anchor capacities, the final design for the anchored structure used six levels (Figures 6 and 7) of three unit temporary SBMAs (Figure 6b) with varying overall length and a working load up to 600 kN (135 kip). On the rare occasion when the installed SBMA did not satisfy the acceptance criterion, additional applications of post-grouting were used, and the anchor retested until the creep criteria was achieved (Figure 7b). The anchoring solution successfully restricted lateral wall deformations to about 7.5 mm (0.3 in) over the maximum excavated depth of about 25 m (82 ft). The use of the SBMA technology and the use of end-of-casing grouting and/or post-grouting resulted in anchor capacities that were more than double those previously achieved in the same ground conditions. Ultimately, the alternative approach and use of the techniques described led to considerable savings to the project by avoiding top-down construction, proposed compensation grouting, and proposed realignment of the existing sewage pipe.

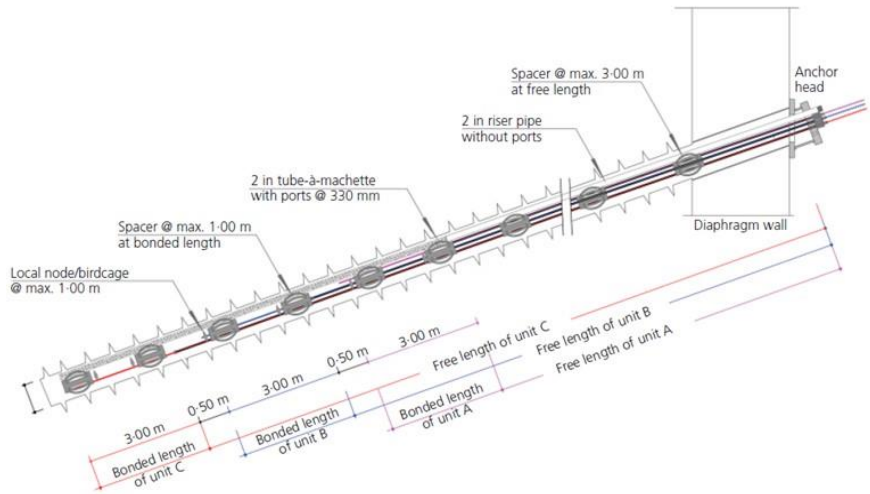
Anchored Diaphragm Wall – Izmir, Turkey

Nearly 1,064 linear meters (3,500 LF) of 800 mm (32 in) thick diaphragm walls in three areas were constructed for the Mahall Bomonti mixed-use development in the Izmir region of Turkey (Mothersille et al, 2018), as denoted by Blocks A, B, and C in Figure 8a. Some 2,600 temporary SBMAs were successfully installed and tested to support the 27,500 sq m (296,010 sq ft) of exposed face of the diaphragm walls, whose excavated depths ranged from 14 to 18.5 m (46 to 61 ft), as shown in Figure 8b.

Anchored diaphragm walls were constructed in highly heterogeneous alluvial soils (i.e., clays, silts, sands, and gravels) with a highly variable strength profile. In the sand and gravel layers, the SPT N-values ranged from 30 to 45 blows/0.3 m (blow/ft) with CPT tip resistance (q_c) values ranging from about 4 to 40 MPa (42 to 418 tsf). In the clay and silt layers, the SPT N-values ranged from 5 to 15 blows/0.3 m (blow/ft) with CPT q_c values ranging from about 0.1 to 4 MPa (1 to 42 tsf). In addition, the depth to the groundwater table was relatively shallow and was located about 2 m (6.6 ft) below the ground surface; artesian conditions were observed around 38 m (125 ft) below ground surface within the gravel layers.



(a)

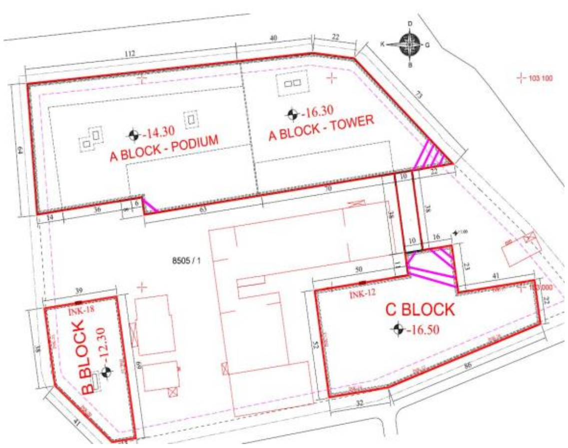


(b)

Figure 6. Schematic of (a) a typical section through 25 m deep excavation with six levels SBMAs and positioning of adjacent utilities and structures, and (b) a three unit SBMA

(a)  (b) 

Figure 7. Photographs of (a) the anchored diaphragm wall with six rows of SBMAs and (b) the testing of production SBMAs using synchronized hydraulic jacks (Mothersille et al, 2015)

(a) 

(b) 

Figure 8. Mahall Bomonti project (Izmir, Turkey): (a) plan view of the three construction blocks and (b) photograph of SBMA anchored diaphragm wall in Block A

A pre-production test program was implemented to verify the assumed anchor capacity of 550 kN (124 kip) could be achieved at the site. Based on the results from several tested single unit anchors and full SBMAs, the anchor working (design) loads were increased to as much as 650 kN (146 kip) and test loads of up to 1,850 kN (416 kip) were demonstrated, which were the highest anchor loads ever achieved in the region. Therefore, the total length of anchors installed at the site for the three diaphragm wall structures was about 55,200 linear meter (181,100 LF), which was a reduction of about 64% from the original design comprising about 153,000 linear meter (502,000 LF) of anchor length. Ultimately, due to the redesign and pre-production anchor testing program, the project realized a savings of up to 60% in construction time and 35% in the total price of the anchoring work.

Permanent SBMAs in Austria

The effective use of the SBMA technology was highlighted on a prestigious project undertaken on the A2 motorway between Graz and Vienna in Austria. The purpose of this remediation project was to replace about 400 previously installed conventional ground anchors, each with a load of about 1500 kN (337 kip), because they had failed due to corrosion of the strands below the anchor head. The originally proposed solutions consisted of installing 400 new conventional ground anchors, one new for one failed anchor. However, SBMA Ltd. proposed an alternative scheme to reduce overall project time and costs by utilizing specialist techniques that were not included in the original specifications. In lieu of installing 400 new conventional ground anchors with a 1,500 kN (337 kip) working load, an alternative approach was proposed and comprised installing and testing 200 SBMAs into the weak rock, each with a working load of about 3,600 kN (810 kip).

Ultimately, the alternative design for this slope stabilization endeavor was accepted, and the final system (Figure 9) consisted of 200 double corrosion protected, permanent SBMAs in accordance with the criteria stipulated in BS 8081:1989 (BSI, 1989). Each SBMA was installed with an overall length of about 82 m (270 ft) and a working load of about 3,800 kN (855 kip). Each SBMA consisted of three unit anchors, which were 6.3 m (21 ft) long, incorporating 6 Dyform strands that were 18 mm (0.7 in) in diameter. In addition, the SBMA system specifically addressed the vulnerable zone with the use of a double plastic strand protection and continuity of corrosion protection below and within the anchor head.

Figure 9. Photograph of permanent SBMAs for slope stabilization (Degendamm, Austria)

Removable Anchors - Corniche, Abu Dhabi

The mixed-use Corniche Towers development in Abu Dhabi, U.A.E., comprised the construction of three new towers, each more than thirty stories in height, to house residential apartments, offices, and retail floors at the podium levels. Below the podium level, there are four levels of common basement to accommodate underground parking. Some 600 temporary ground anchors were used around the main excavation combined with steel strut pipes, used at the corners and along the short-span corridor, support the diaphragm and secant pile walls that formed the shoring structure for the 20 m (66 ft) deep excavation. Along the Corniche Road side, removable ground anchors with working loads varying from 915 to 1,125 kN (206 to 253 kip) were implemented to avoid conflict with future infrastructural development plans proposed by the municipality (Figure 10). The AnchorTest™ (AnchorTest, 2015) tablet-based software was utilized for the real-time and post-testing analysis and data management of the removable SBMAs that were used for the temporary foundation works.

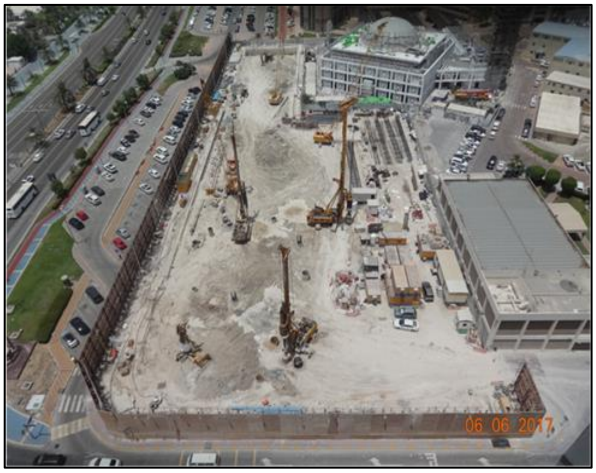


Figure 10. Photograph of construction site for Corniche Towers development (Abu Dhabi, UAE)

The design of the removable SBMAs was optimized by using the results of a preliminary investigation test program in which vertical test anchors and removable anchors were installed. Removable anchors were incorporated into the test program and subjected to suitability testing and to evaluate their removability. During these test trials, a maximum test load of 1,700 kN (382 kip) was applied to and successfully resisted by the test anchors, and all of the associated data was analyzed real-time with the tablet-based software (Figure 11a). As shown in Figure 11b, the vertically installed removable anchors were tested up to a maximum test load of 1,150 kN (259 kip), which was 1.25 times the required working load, in accordance with requirements of the applicable code provisions of BS8081:1989 (BSI, 1989). As part of the QA/QC protocol requirements, the tablet-based software was used to monitor and analyze real-time and record the routine onsite acceptance testing work before each production anchor was locked-off.

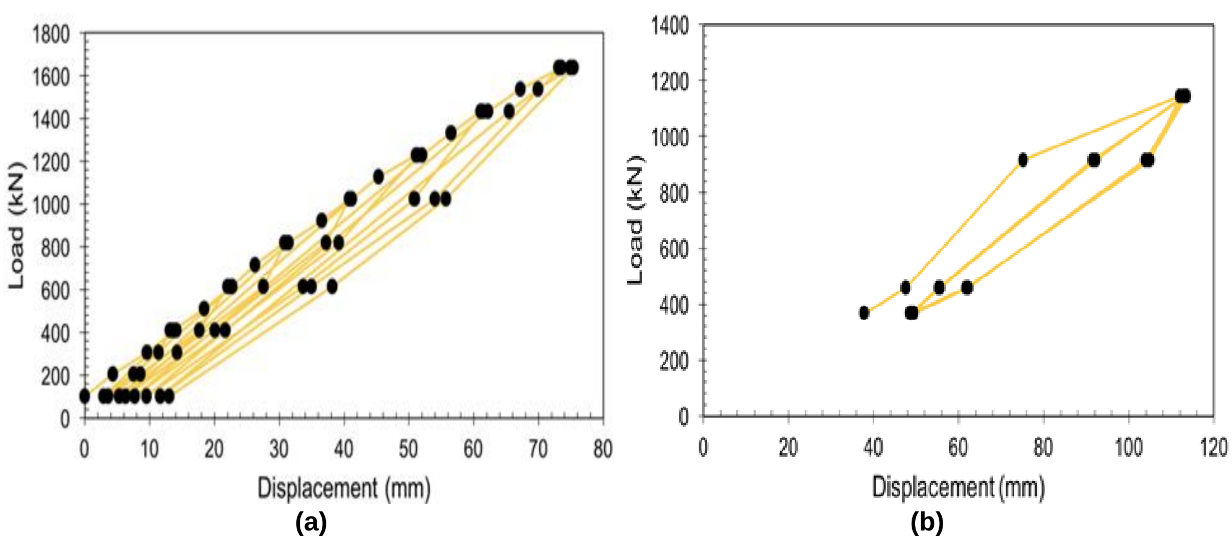


Figure 11. SBMA test results: (a) proving test for anchor A4, and (b) suitability test for removable trial anchor R1 using a single hollow ram stressing jack

CONCLUSION

The relatively high load transfer efficiency of short bond lengths is exploited in the SBMA system which is now in international use. This system will be especially valuable in earth retention systems in urban areas. The introduction of a new anchor system with more than double the working capacity of conventional anchors in soils and weak rocks has provided a supplementary economic benefit in the use of the anchor systems. One of these is the advantage of open inhibited working space for construction within the deep anchored excavations. High load and low load capacity anchor systems now exist which allow the total removal of the steel tendon from the anchor borehole and from the ground. This removal after temporary provision of safe support of the excavation makes the use of anchors more 'environmentally friendly' and more acceptable to adjacent land owners. The use of the tablet-based software platform, AnchorTest™, for the analysis and management of load/extension data has proved to be an effective tool and has been successfully implemented on SBMA projects worldwide. As observed with increasing frequency throughout the construction industry, tablet-based (real-time) software outperforms and exceeds the capabilities of laptop-based spreadsheets in the field for several reasons, including ease of use, enhanced user interface, user customability, and web-based data management. Select benefits of the tablet-based anchor analysis and data management system include superior user interface (i.e., iPad vs. laptop), more robust for field applications, digitized immediate cloud storage, instant third-party access for assessment and decision making, real-time assessment of anchor behavior against acceptance criteria, and facilitates all major international codes within a single package.

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