

Historic and current practice of excavation along the Atlantic Seaboard, Cape Town

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ABSTRACT: The Atlantic Seaboard, extending from the V&A Waterfront to Hout Bay, Cape Town, features steep topography that necessitates deep, unbalanced hillside cuts to create level platforms for construction preventing encroachment into neighbouring properties. This paper examines historical practices in the region for creating and supporting these hillside cuts and presents a case study as an example of the lateral support systems employed in the area. Additionally, the paper offers recommendations for approaching site development and lateral support in this area.

1 INTRODUCTION

The Atlantic Seaboard of Cape Town, South Africa, is famous for its natural beauty, beaches, and expensive real estate. Stretching from the V&A Waterfront to Hout Bay, the area has a rich history, with significant development occurring in the late 19th and early 20th centuries. Water supply and transportation improvements, such as the motor car and trams fuelled this growth.

Development in the area took place mostly on steep slopes requiring deep excavations. This paper

will examine the region's history and current excavation practices for deep excavations along the Atlantic Seaboard. Figure 1 provides an aerial photograph of a portion of the seaboard and the areas and sites discussed in this paper.

2 HISTORIC BACKGROUND

Dutch settlers arrived in Cape Town in 1652, but it was not until much later that areas like Bantry Bay, Clifton, and Camps Bay began to develop.



Figure 1. Areas and sites referenced in this paper (Google Earth Pro 2025)

Initially, the Liesbeeck Valley to the east of Cape Town centre, with its fertile land, was more desirable for farming and provided supplies to ships travelling to the spice islands. The Atlantic Seaboard's slow development was due to challenges including difficult access, lack of water, and long travel times from the city centre.

In the early 20th century, modern transportation such as trams, trains, and motor vehicles made travel between these areas and the city feasible. However, parts of the region, like Greenpoint and Sea Point (to the north of Bantry Bay in Figure 1), lacked a reliable water supply. The construction of roads through steep terrain and access to water sources were key to the area's development (Schrire 2003).

By 1863, Greenpoint and Sea Point had a population of 700, which was expected to soon double, prompting a pipeline to be built from the Round House wells (Site 1) to Sea Point. Bantry Bay was granted in 1804 and included conditions such as water access to the public and public access to Kloof Road. Large boulders obstructed further development where Victoria Road is located today. By 1902, the land was subdivided into plots (De Beer 1987).

In the late 1800s, roads such as Kloof Road (higher road in Clifton) and Victoria Road (lower road in Clifton) were constructed to connect the area. Kloof Road was formalised by Thomas Bain for the Queen's Jubilee in 1887, and the work was done by convict labour. These roads, particularly in areas with soft granite rock, were built with steep cuts (see Fig. 2) (de Beer 1987). Some erosion and failures have occurred over time, but the roads have remained functional since then.

The first tram service began in 1901, from Sea Point to Camps Bay over Kloof Nek via Camps Bay Drive. The tram service continued until 1930 when the road was converted into a motor road (Schrire 2003). In 1969, a petition from property owners in Camps Bay sought to prevent high-rise developments on the beachfront, leading the City Engineer to limit buildings to three stories (de Beer 1987).

3 GEOLOGICAL AND TOPOGRAPHICAL SETTING

3.1 Topography

The area is typically steeply sloping with incised streams and occasional minor rock cliffs. Occasional small coastal flats in the bays and on a remnant wave-cut platform at the ends of the promontories, are also present. Development is restricted to below the 180 m contour on average and is largely on steep slopes of between 15 and 34 degrees up to near-vertical in places. Access onto most sites is severely restricted by neighbours, busy roads and is often via walkways only.



Figure 2. Historic photo of Clifton, early 20th century showing Kloof Road above Victoria Road

3.2 Geology

Most of the development in the area has taken place where it is underlain by bedrock comprising shales and lesser graywackes and quartzitic sandstones of the Tygerberg Formation, Malmesbury Group to the north, and granite of the Peninsula Pluton, Cape Granite Suite to the south of the contact between the two. These are locally weathered to greatly varying depths with profiles grading from residual soil at the top to hard rock at depth. Occasional small dolerite dykes, that intruded the shales and granites, are present.

Overlying these bedrock profiles, there exist areas of transported materials of greatly varying thicknesses, ages, degrees of cementation and mixed compositions ranging from clays to coarse boulder talus. Localized pockets of silty alluvium also occur in the lower reaches of the valleys and close to the shoreline in the bayheads where marine sediments are also to be found. Much of the colluvia is derived from the shales and sandstones of the Graafwater Formation and the quartzitic sandstones of the Peninsula Formation that crop out in the steeper parts upslope of the area being considered.

A feature of the area is the presence of remnants of the old African Erosion Surface (Maud and Partridge 1987) where it has not been totally or partially eroded away (see shaded area in Fig. 1). It is characterised by deep chemical weathering of the bedrock and of the older colluvia along a contour between the elevations of approximately 50 m and 150 m.

A consequence of the above is that excavation and lateral support ranges from being in residual materials, soft rock through hard rock and residual clayey soil to completely weathered kaolinitic and illitic silty clays in the granite and Malmesbury Group areas, respectively. In the transported materials, conditions range from cemented mixed colluvium, which is weathered, to clayey silt with highly weathered boulders beneath the African Erosion surface, sandy colluvium with sandstone boulders and gravel, loose silts and sands. A common occurrence is also the presence of large, moderately hard and mostly case hardened, granite core-stones within the residual soils and

weathered colluvium. It is not uncommon for any or many of these conditions to be juxtaposed on a single site.

3.3 Geological Structure

The main near-vertical joints throughout the area which typically dip at up to 75° both sides of the vertical, strike NNW-SSE with a near-orthogonal set striking ENE-WSW. A subsidiary near-orthogonal two sets strike WNW-ESE and NNE-SSW with a lesser well defined or continuous two sets variably striking N-S and E-W. The trend of the near-vertical isoclinal folding in the Malmesbury generally corresponds with that of the NNW-SSE joint set. Flow bedding within the granite is variable but predominates at a 23° dip to the WSW. Figure 3 provides a lower hemisphere stereographic plot of poles to planes for granite in Clifton.

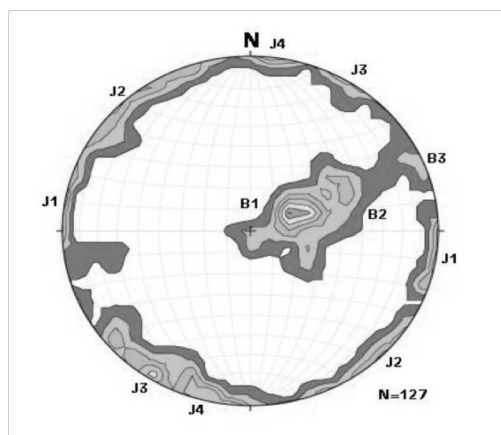


Figure 3. Lower hemisphere plot of poles to planes for Granite in Clifton

Whereas these joint sets are significant in terms of smaller wedge or toppling type failures of excavation faces and should be used for the design of cut slopes, the occurrence of infrequent and randomly orientated joints are of greater concern. Small and large-scale slip failures have been recorded at angles of greater than 49° in the granite rock and 34° in the Malmesbury rock. Much lower values are possible in the residual and transported clayey silts and sands.

A feature of the two main joint sets is manifested along the coast by the log-spiral shapes of the bays with beaches. These are enclosed by NNW trending rock promontories that extend inland as more competent ridges of rock separated by bands of more closely jointed, and hence more easily weathered and eroded, rock to form the bays with valleys behind, extending inland.

This NNW-SSW joint trend has also resulted in the marine erosion of deep gullies. These gullies follow the same trend in the bedrock that can be seen along the shoreline, but which extend beneath the transported materials covering the remnants of the wave cut platform and other minor marine terraces.

3.4 Slope Stability

In the undisturbed state, most of the transported materials reside at their natural angles of repose and, particularly in the more clayey materials, are subject to very gradual downslope creep promoted by seasonal wetting and drying. Such creep can increase the earth pressure acting on a lateral support system over time. The rocks reside at much steeper slopes with little instability other than the occasional rockfall and dislodged core-stones that can travel large distances threatening structures and motorists. However, the weathered granite rock rapidly weathers further upon fresh exposure such that what was a stable soft rock cut face becomes a collapsed soil face within a period of a year to 30 or so years, depending on its initial degree of weathering. This is also clear from fills supporting Victoria Road which have settled in time due to such weathering altering the composition.

In some areas of colluvium with clays at the base which are subjected to groundwater fluctuation, there exist large areas residing in a quasi-stable state with respect to the downslope sliding or creep, where alterations in the water regime or destabilisation by excavation and removal of lateral support can bring about rapid downslope movement. Such areas can extend over a large area, affecting numerous properties and long sections of roadway as has been experienced around Cape Town in, for example, Camps Bay, Simonstown, Hout Bay and Bakoven.

3.5 Groundwater

Groundwater levels fluctuate seasonally by typically 1.5 m with flows and elevations reaching their peak around the end of September and their lowest around the end of March. Flows within the bedrock are joint controlled. A perched water table typically develops at the base of the more permeable sandy colluvium on the surface of the underlying clayey residual material or older clayey colluvium. The infilled valleys can carry significantly large, sub-surface water flows. The majority of slope stability problems encountered involve some contribution by groundwater.

4 HISTORIC DEVELOPMENT (LATE 19TH AND EARLY 20TH CENTURIES)

Cut slopes in colluvium, residual rock, and soft to medium-hard rock were typically made at a 1.5V:1.0H (56°) angle without support, while cuts in hard rock were near vertical. Some of these cuts reach up to 12 m in height. Residual granite and colluvium generally lack true cohesion, as they disintegrate when saturated; however, they exhibit some capillary cohesion or cementation.

In a limit equilibrium back analysis of a typical 12-metre-high slope with a natural slope angle of 35° ,

with no phreatic surface, assuming an angle of shear resistance between 30° and 35°, a minimum cohesion value of 10–15 kPa is required to maintain a stable slope (with a factor of safety ≥ 1.0) at a cut slope angle of 1.5V:1.0H. These values can be achieved using Fredlund's (2019) marching forward method, which accounts for the increased shear strength in the unsaturated state even if the material has a high degree of saturation.

When slopes are cut vertically rather than at a slight batter, a comparable 7-metre-high cut in the same topography and for the same road width, would require at least 25 kPa of cohesion for stability. This underscores the advantage of cutting at a shallower batter. To achieve a Probability of Failure (PoF) of $<10^{-5}$ the cohesion value should at least be 50 kPa. Shallow cuts are sensitive to small changes in cohesion and shifts in moisture conditions and corresponding changes in capillary cohesion can significantly impact the PoF. Consequently, assigning a fixed PoF to these slopes is challenging, as it varies with seasonal and annual changes in the moisture regime.

Many of the early cut slopes were covered with a concrete facing in the years following the original cutting to prevent erosion, weathering and significant changes in the water regime.

If only the bottom metre of the cut face becomes saturated, the cohesion of the material above it cannot be sufficiently increased to achieve a factor of safety greater than unity. Therefore, if residual material or colluvium becomes saturated—even at shallow depths—the slope at these angles is likely to fail.

The acceptable PoF depends on factors such as repair costs, environmental impact, risk to human life, and the potential for damages. During the time of construction, these slopes would have classified as high-risk-low-consequence due to low annual average daily traffic (AADT), absence of water channels, and lack of expensive properties above. However, many of these slopes today would be classified as high-risk-high-consequence due to the presence of costly properties situated above them, increased shade preventing slope drying and associated changes the moisture regime, increased vegetation that opens rock joints, and increased stormwater channelling.

Historically, foundations were shallow and highly loaded or taken down to the rockhead. Excavations were typically terraced and seldom into hard rock.

5 GEOTECHNICAL DEVELOPMENT

5.1 Gunite/Shotcrete in South Africa

Gunite, a form of sprayed concrete, was developed in the United States around 1910. It gained significant attention for its versatility and efficiency in a range of applications, from structural reinforcement to erosion

control. The technique was introduced to South Africa in 1920, where it quickly became popular (Yoggy 2005).

5.2 Ground anchors in South Africa

Although ground anchors were widely used in dam construction, with the earliest known application in the world being at Algeria's Cheurfas Dam in 1934, their first known underground use in the world, to provide lateral support, occurred in 1953 at the East Rand Proprietary Mines (ERPM) in Johannesburg, within a sub-vertical shaft (Parry-Davies 1967). Following this, ground anchors became increasingly popular for lateral support, with the first known application in Port Elizabeth between Chapel and Main Street in 1957. Around the same time, similar projects were underway in Cape Town, though the exact locations of these sites are not known (Parry-Davies 1967). Germany also began using ground anchors for lateral support during this period.

The early 1960s saw numerous deep excavations in Johannesburg's central business district, with the 20-metre-deep excavation for the South African Associated Newspapers basement being one of the first. By the 1960s, Johannesburg was home to some of the world's deepest basement excavations.

To the authors' knowledge, the first building in Clifton to use ground anchors was The Beaches (Site 6 in Fig. 1), completed in 1969 (SAICE 1994). Prior to this, buildings were typically constructed on terraced ground, which required small retaining structures, usually located in colluvium. Over time, some of these terraces have experienced significant rotation due to creep, leading to the need for stabilisation.

5.3 Geonails in South Africa

After the successful application of geonails in Germany and France around 1979, the technology was trialled in 1987 in Krugersdorp, South Africa. At that time, the trial was conducted by GeoFranki (Schwartz 1989). The results of the trials helped establish geonails as a reliable method for ground stabilisation in South Africa.

6 MODERN-DAY DEVELOPMENT

In the 1960s, four large apartment blocks were developed: Valhalla (Site 3), San Michele (Site 4), La Corniche (Site 5), and The Beaches. To the authors' knowledge, only The Beaches (Site 6) was constructed using anchors and shotcrete (Civil Engineering, 1994), although a few of the terrace retaining walls were retrofitted later with rock bolts and anchors. Valhalla, San Michele, and La Corniche, on the other hand, were built using minor terraced cuts, typically around 1.5 metres high, with a deeper cut concrete retaining wall on the lower portion of the site.

The construction of these glamorous and opulent structures was met with dismay from Clifton residents, who felt they detracted from the area's charm, which had been defined by its historic bungalows dating back to 1886 (de Beer 1987). In 1984, the decision to designate zones around Clifton's 2nd, 3rd, and 4th Beaches, Glen Beach, and Bakoven as national monuments sparked significant criticism (de Beer 1987). The aim of this move was to preserve the unique character and charm of the area, including its historic bungalows, and to prevent the development of large apartment blocks similar to those at Clifton's 1st and 2nd beaches from encroaching on Clifton's 3rd and 4th beaches.

Since 1987, some of the largest excavations in the area have included those at Dunmore Apartments (Site 7), Eventide (Site 8) and Clifton Terraces (Site 9). From a foundation perspective, most large developments use raft or pad foundations on solid rock. For properties located above unsupported road cuts, the cut slopes are typically on council land, making it difficult for property owners to stabilise the slopes. As a result, these owners often rely on piled foundations and beams to ensure that the weight of the structure is transferred deeper into the soil profile, preventing excessive surcharge from acting on the unsupported cuts.

Permissions for grouted anchors are becoming extremely difficult to obtain, and for the development of any site in the region, it is often best to develop a scheme without any grouted anchors having to protrude into neighbouring properties. One such case study is provided in the following section.

7 CASE STUDY

7.1 Location and Problem Statement

An overall maximum cut of 43 m was required for the construction of a 12-level apartment block in Clifton (Site 9). This was achieved through a four-tier system, with the maximum single vertical cut reaching 26 m in height. This remains the deepest single excavation created in Clifton to date for a single development. The site is located next to Clifton Steps to the north, a servitude to the south, public open space to the east, and the 27 m deep cut for Eventide to the west across Victoria Road. Clifton Steps and the servitude are only 3-4 m wide, with privately owned land adjacent to both. Grouted anchors were not permitted to be installed in the privately owned land to the north and south; however, permissions were obtained from the council to install permanent anchorages within these servitudes and in the public open space to the east.

Geology

The site is typically covered by a 1 m thick layer of sandy colluvium, which rests on a 1 m thick residual

granitic soil layer that transitions into very soft rock and then hard rock at greater depths. Contours of the bedrock hardness were determined using data from surrounding outcrops, joint orientations, and borehole investigations.

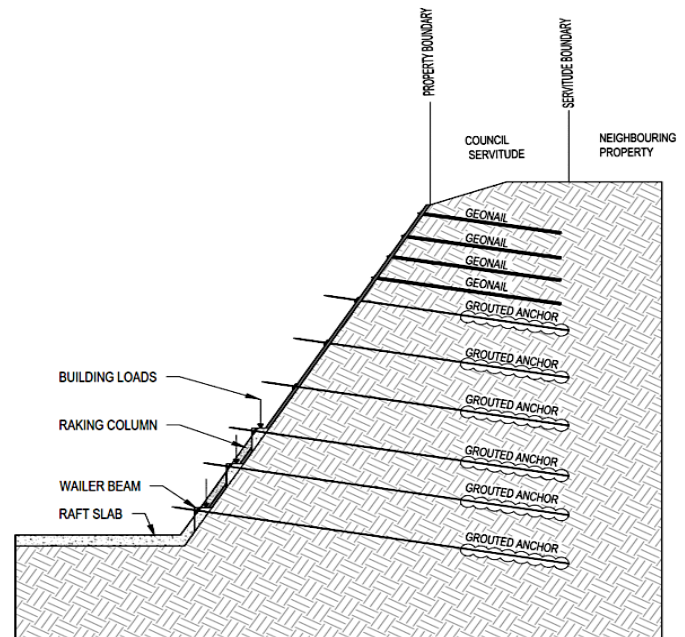


Figure 4. Sloped lateral support on southern and northern faces

7.2 Solution

Back analyses were conducted using slope stability software to evaluate the historic cut, slopes, and structures that were present on the site and surrounding area in order to estimate the minimum shear strength parameters. These analyses employed Mohr-Coulomb, Hoek-Brown, and Barton-Bandis strength models. The strength values were adjusted and rationalised to achieve similar results in terms of factors of safety for all analysis methods used. Subsequently, single wedge analyses were performed to determine the required horizontal force to stabilise the cut, considering varying friction angles and cohesion values. This was done in 3 m increments to assess the increase in horizontal force with depth for each segment.

The design incorporated a nailed shotcrete facing interspersed with walers with permanent grouted anchors. On the eastern and northern faces, the lateral support was battered at a 60° angle from the horizontal (Fig. 4), starting from the property boundary. This resulted in the lateral support toe line stepping into the site at an angle, nonparallel to the boundary. The reinforced concrete frame on the southern and northern faces had to be supported on these slopes. Although the bearing stratum had sufficient bearing capacity, sliding was possible, and an additional frictional component needed to be developed. This was overcome by supporting the waler beams with

raking columns that transferred the load to a concrete raft.

Subsequently, 2D finite element (FE) analyses were performed to predict the deformation using both Mohr-Coulomb and Hoek-Brown constitutive models. The total displacement predicted by the Mohr-Coulomb model after excavation was 32 mm, and 75 mm after construction of the building on the top tier. In comparison, the Hoek-Brown model predicted 32 mm and 37 mm of displacement, respectively.

Additionally, a 3D FE analysis was conducted, which predicted a total displacement of 20 mm after excavation. This displacement is lower than the 32 mm predicted by the 2D analysis. This difference can be attributed to the more accurate representation of the failure mechanism in the 3D model, where additional strength from the sides of the slip surface is taken into consideration. Furthermore, in some cases, if the soil is able to arch between the two lateral support faces, the pressure could be further reduced, as the failure mechanism would resemble that of a semi-silo.

7.3 Construction and Ground Movement

Ground movement measurements were undertaken with accurate survey readings. The final total displacement measured, after construction of the building on the lower 25 m high eastern face was 41 mm which aligns well with that predicted from the Hoek Brown 2D analysis. A photo of the excavation is provided in Figure 6.



Figure 6. Photo of Clifton Terraces lower cut (H&I 2021)

8 CONCLUSIONS

Developments along the Atlantic Seaboard have always been faced with the need for deep excavations. The risk profile associated with original cuts created in the late 19th century has changed due to the expensive properties now above them and increased vegetation growth, shade and traffic.

Developing sites along the Atlantic Seaboard is becoming more challenging due to the difficulty in

securing grouted anchor permissions from neighbouring properties, especially as discussions are increasingly being directed through legal channels.

The development of Clifton Terraces illustrated the difficulty of developing in this area and the innovative design that needed to be undertaken to ensure that a feasible development could be undertaken.

9 RECOMMENDATIONS

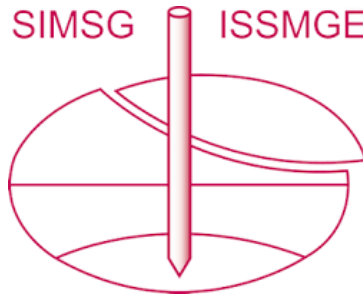
Due to the increasing difficulty in developing sites on the Atlantic Seaboard the following recommendations are provided:

- 1) The initial topographical survey should extend to a distance at least equal to the depth of the proposed excavation on all sides of the site including all basements and foundations.
- 2) A concept should be developed to establish what can be constructed within the site boundaries without obtaining neighbour permissions.
- 3) If such an option is feasible, then the architectural scheme should be developed within the confines of what can work geotechnically.
- 4) If no feasible scheme can be found without moving closer to the property boundaries, the neighbours should be consulted with a feasibility design for an in-principle agreement to install temporary or permanent grouted anchors in their properties before commencing with the detailed architectural, structural and geotechnical design.
- 5) The developer should propose to the neighbours to engage with an independent geotechnical engineer to review the request and agree to reimburse them for the professional's fee.
- 6) If neither option works, internal propping by struts and rakers, or top-down, half-width construction may need to be considered.

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