

Reinforcing cliffs and walls

Stainless steel ground and rock anchors keep land from sliding and walls from tumbling. They were used recently to stabilize and reinforce a crucial sea wall in England and an unstable rock face at the site of important antiquities in Greece. Molybdenum provides the added corrosion resistance necessary for a long service life even in the most corrosive environments.

Building a seawall to withstand the biggest waves

On the night of February 4th, 2014, a major storm hit South West England. At the sea-side resort of Dawlish, huge waves crashed against the sea wall which retains the coast-hugging mainline rail link from London to Cornwall. The waves washed out the granite facing blocks and eroded the back fill, leading to failure of a 100 meter length of the wall. The railway was left suspended in mid air and collapsed into the sea, severing this strategically important route into Cornwall.

Network Rail, the owner and operator of most of the rail infrastructure in Great Britain, called for urgent repairs to the track and seawall. Houses in the vicinity also required stabilisation because their foundations had been ripped away by the sea. In addition, the Global Crossing Cable, a major communication line laid on the Atlantic seabed connecting New



The train track in Dawlish was left suspended in mid-air after storms battered the sea wall in February 2014. © Network Rail

York and London, runs alongside the main railway line and had to be supported. Rebuilding and fortifying the 100-meter breach of the sea wall began immediately and a crew of more than 300 people worked round the clock in order to complete the repairs in time for the Easter holidays – a busy time for that particular train route. One of the challenges facing Network Rail and the various contractors was the continuing stormy weather. There

were exceptionally high tides and rough seas, which limited the time that the teams could work on site. Huge waves caused by another severe storm a week later led to further damage to the sea wall.

A critical component of the repair was the use of 160 fully threaded stainless steel anchor bars to tie together 5,000 tonnes of concrete in the construction of the wall. The anchors were part of the Grip-Bar system manufactured by Sheffield-based company Stainless UK. They were 6 meters long, 36 mm and 39 mm in diameter and had 20 mm thick end plates and fixings. Type 316 austenitic stainless steel was selected for the anchors. This grade of stainless steel contains about 2% molybdenum which gives improved pitting and crevice corrosion resistance in chloride-containing environments.

Stabilizing the Acropolis cliff face

Stainless steel anchor bars have also been used to stabilize part of the northern cliff face of the Acropolis in Athens. This was necessary to prevent the cliff from collapsing onto the sacred cave containing the Klepsydra Spring, one of Athens' ancient sources of water. Other ancient sanctuaries which date back to Neolithic times (3500–3000 BC) were also in danger. Landslides were common over the centuries and the cliff collapsed onto the cave in the 1st century AD. Two thousand years later the continuing threat of crumbling of the unstable rock face led to a major renovation project to preserve this World Heritage Site. Type 316 anchors with diameters of 16 mm and lengths of up to 6 meters were fixed into the rock using resin capsules and steel end plates. ➤



Grip Bar stainless steel tie bars being installed in the base of the new concrete sea wall at Dawlish. © Network Rail



The stainless steel anchor bars which stabilize the northern cliff face of the Acropolis and their end plates are very unobtrusive – just barely visible in the foreground of the picture. © Stainless UK

Stainless steel anchor bars

The stainless steel anchors are made by cold drawing which produces high strengths, nearly three times higher than the strength in the annealed (softened) condition (see table). The bars are threaded along their entire length via a cold forging process, forming a custom-made, coarse pitch. The technique results in localized strengthening of the threads and the pitch size facilitates the attachment of fixings. The bars can be cut to length on site without damage. Traditional stainless steel rock anchors are made of reinforcing bars with a fine threaded section of fixed length on one end. The threads are tapped, which does not add to their strength. Comparative testing at the University of Sheffield showed that across a range of

Ground and rock anchors are used to restrain and stabilize tunnels, rock faces, cuttings and slopes as well as provide support to retaining walls. The anchor is under tension and is installed inside a borehole. Its end is generally grouted into deeper sound rock with cementitious or resin grout. The anchor applies a restraining force to the rock face or slope via a plate. **Soil nails** work on a similar principle and are used for slope stabilization. Anchors can be used to stabilize individual blocks or in a grid pattern to improve stability of an entire rock face. They may be temporary or permanent and, dependent on the environment, have varying durability requirements. Design lives exceeding 100 years are not an uncommon requirement for permanent anchors.

Minimum mechanical properties for annealed and cold drawn bar

For bars 10–48 mm diameter	Annealed	Cold drawn
0.2% proof strength	200 MPa	650 MPa
Ultimate tensile strength	500 MPa	750 MPa
Elongation	40%	15%



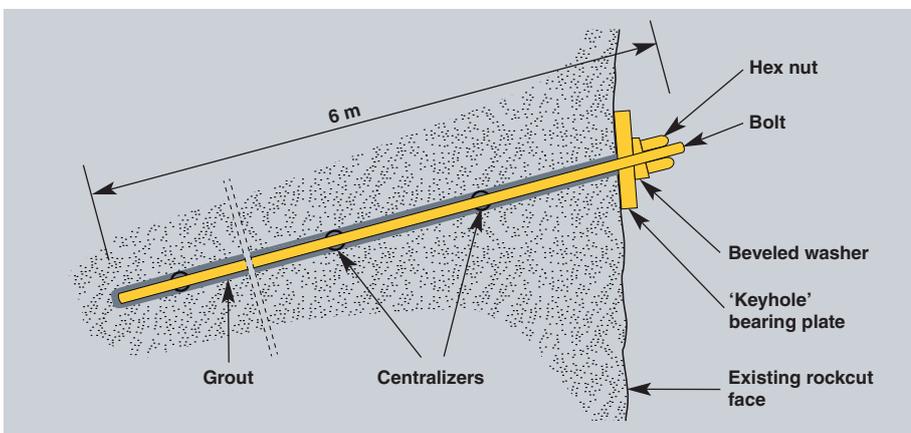
The cold forged thread of the rock anchor on the left is much stronger and provides much better “grip” than the traditional reinforcing bar profile. © Stainless UK

grout strengths, the coarse-pitch anchor system had a bond strength, up to the first slip, of at least 2.8 times that of equivalent stainless steel reinforcement bar.

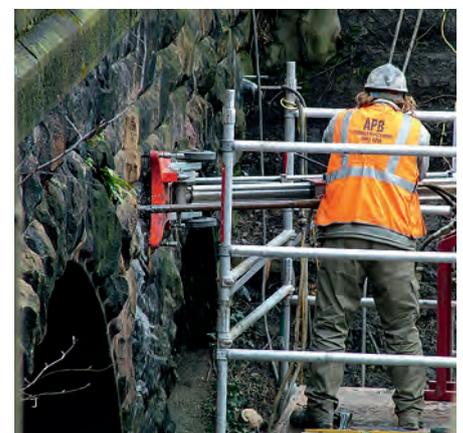
Stainless steel anchor bars are used for soil nails and ground anchors to stabilize soil slopes or to anchor structures in the ground. They also serve as cross ties to strengthen buildings and bridges, as holding down bolts, and to secure coastal defense walls and slabs. Their relatively high ductility also makes them ideal for areas of seismic activity. Compared

to carbon steel alternatives where the required additional corrosion protection can lengthen the installation process, stainless steel installation is quick and easy.

Stainless steel is becoming an increasingly popular choice of material for ground and rock anchors. The inherent corrosion resistance, especially of the molybdenum-containing grades, leads to a durable, long-life solution. This helps to protect infrastructure investments in construction, transport and communications. (Nancy Baddoo)



The 6 meter long rock anchors are inserted in pre-drilled holes where centralizers keep them centered before the grout is injected along the entire length of the anchors. After the grout has cured, the nut on the outside is tightened to put the whole system under tension.



Drilling of the bore hole where a Grip-Bar will be installed to stabilize this old stone bridge. © Stainless UK