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Environmental
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COMPREHENSIVE GEOTECHNICAL & ENVIRONMENTAL ENGINEERING SERVICES
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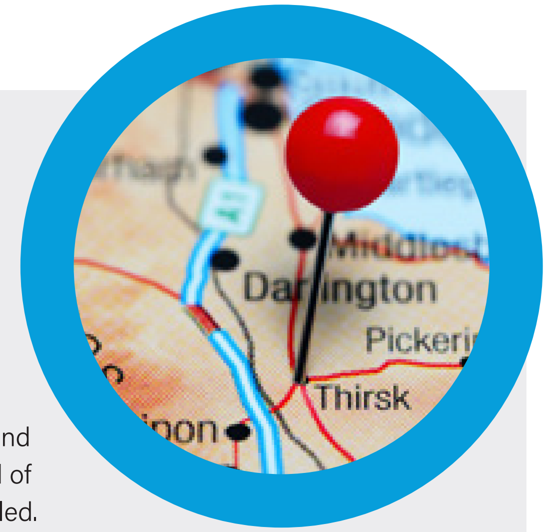
CASE STUDY 06

Safeguarding history at **Kirby Knowle Castle:**

A GEOTECHNICAL CASE STUDY



// THE PROBLEM

Originally built in the 13th century, the stately, Grade II listed Kirby Knowle Castle, with its 37 acres of formal gardens, woodland and open parkland, sits high on a hill overlooking Thirsk and the glorious North Yorkshire countryside.

This magnificent building is now the private residence of **David Kempley**, and in December 2019, he faced a significant problem. After a prolonged period of heavy rainfall, the retained slope at the south east corner of the rampart failed.

Picture supplied by **crismatthews.com**

// TAKING ACTION: INITIAL SURVEYS AND RESEARCH

David asked RGS to examine the slippage and assess the risk to the main castle building. Our initial site visit revealed that the rampart was extremely vulnerable, but we were also able to reassure David about the overall stability of the castle itself. With early visits showing that movement was progressive, we suggested remedial measures to reduce the impact of the slope movement on various parts of the building.

The iterative nature of our design work is fundamental here. When considering the remediation of failed slopes, we are not only undertaking design, but crucially, we are also carrying out rigorous research. As highly experienced geotechnical engineers, we consider a solution, then test and analyse to establish whether it works. We can then modify the works in an iterative process to achieve the most effective remediation.

This phase of the work involved a comprehensive desk study of the geological setting. It indicated that no superficial deposits would be revealed beneath the castle, although they would probably be present beneath the low-lying area to the south. The table below summarises the geology.

We also discovered a spring line at the transition between the Dogger Formation and underlying Whitby Mudstone Formation, which issued from the scarp slope below the castle wall.

During this phase of the work, we consulted the BGS publication, Landslides and mass movement processes and their distribution in the York District (Sheet 63).

This document describes several landslips within the Whitby Mudstone Formation and discusses in detail a recent landslide at Kirkham Priory, which is in the same geological sequence as the castle. In that case the back scar of the landslide lies at the boundary between the Dogger Formation and underlying Whitby Mudstone Formation, as is the case at the Castle.

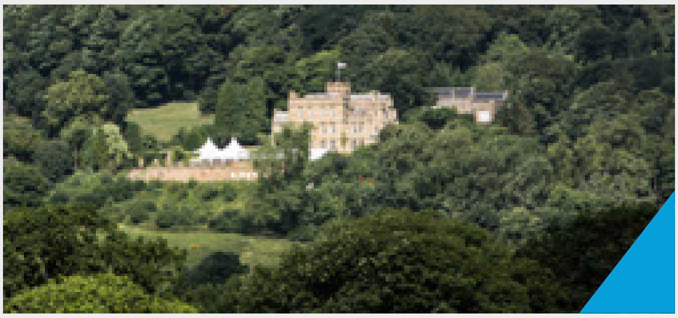


Table 1: Geological Data for the Site

Strata Type	Strata Name	Outcrop Description	Description
Superficial Geology	Vale of York Formation	On the low-lying land to the south and south-east of the Castle	Dominantly glacial till (sandy clay, clayey sand and clay with gravel and boulders) with interbedded sand, gravel and laminated clay.
Solid Geology	Saltwick Formation (Lias Group)	Outcropping beneath the Castle buildings and front terrace to the Castle.	Grey mudstone, yellow-grey siltstone and yellow, fine to coarse grained sandstone (fluvial, fluvio-deltaic and paralic lithofacies). Sandstones commonly display sharply erosional bases channel fill bedforms.
	Dogger Formation (Lias Group)	Below the Saltwick Formation, outcropping beneath the front ramparts to the Castle and extending part way down the slopes to the south and east.	Grey weathering to yellow sandstones and ironstones are characteristically highly bioturbated and yield marine fossils including bivalves and scattered ammonites; corals, bryozoans, crinoids and brachiopods are locally present in the limestones.
	Unconformity		

Sources: British Geological Survey (NERC) Map Sheets 52; Thirsk; Solid Edition and Drift Edition, and Geology of Britain Viewer [online resource from www.bgs.ac.uk].

// PHASE TWO: A THOROUGH SITE INVESTIGATION

Prior to the investigation, we formed the hypothesis that the prolonged spell of extremely wet weather immediately prior to the initial landslip had activated (or reactivated) the buried spring line on the scarp slope. The water had softened and lubricated the interface between the retained soil embankment and natural deposits, resulting in the slippage.

We therefore carried out a detailed site investigation which included eight windowless sample boreholes, eight dynamic probes and two hand-held windowless sample boreholes. In addition, we also used our **PANDA® Penetrometer** to assess the depth of the failed soil near to the toe of the slope. We fulfilled the investigation between 13th and 15th November 2019 and issued a comprehensive report on 17th December 2019.

The report considered:

a) a narrative outlining the site visits and letter reports up to the issue of the Geotechnical Report

b) the geological setting, including information on historical landslides nearby

c) strata conditions revealed during the investigation

d) insitu and laboratory test results

e) geotechnical properties employed in the analyses of results

f) discussion of ground conditions, including:

  a. potential modes of failure
  b. temporary remedial measures
  c. permanent remedial measures, including comments on:
    i. groundwater control
    ii. toe stability
    iii. slope stability
    iv. general comments.

// ON THE BASIS OF THIS INFORMATION AND THE RECOMMENDATIONS WE MADE, DAVID ASKED RGS TO PREPARE THE NEXT STAGE -

A GEOTECHNICAL DESIGN REPORT

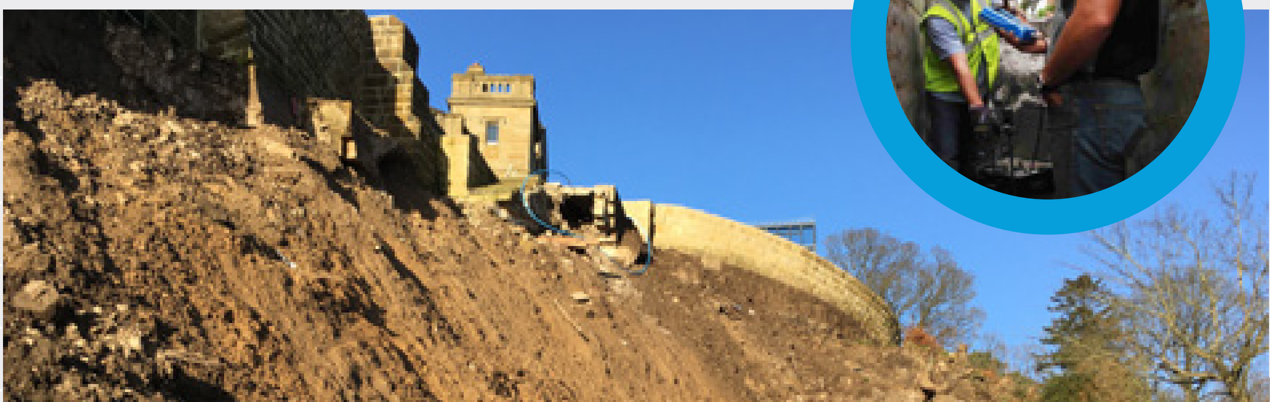
FOR THE REMEDIATION WORKS.

// DESIGNING THE SOLUTION

The **Geotechnical Design Report** summarised our Geotechnical Report as follows:

Table 2: Geotechnical Report Summary

Item	Comments
Problem	Large landslip immediately adjacent to the ramparts.
Geology	Solid geology comprises Dogger Formation (sandstone) over Whitby Mudstone Formation (mudstone).
Historical Landslides	There are several landslides within the same geological sequence. Published data from these failures have been reviewed.
Strata Conditions	Generally made ground or disturbed ground over the weathered fraction of the Whitby Mudstone Formation (re-covered as clay). On the higher ground the weathered fraction of the Dogger Formation was encountered, which was recovered as silty sand.
Groundwater	No obvious water strikes recorded - Soil at various horizons was found to be wet (ie water softened).
Modes of Failure	There are three main forms of landslide observed at this site. ■ A significant wedge type failure to the east of the south east corner of the ramparts. ■ Rotational failure to the north of the wedge failure. ■ Transitional landslide, developing into a flow, to the south of the wedge failure



The Design Report then considered the temporary remedial works undertaken, which comprised:

a) the removal of all of the failed boulder retaining wall, thus reducing the load near the slope crest

b) removing fallen trees to enable access (tree roots were left in place as they supported slope stability in the short term)

c) removal of soil formed against the remaining large trees

d) smoothing off the site to enable the free flow of water over the failed ground

e) construction of two counterfort drains down the slope and through the slip material to the south and south west corner of the rampart.

The permanent remedial works needed to stabilise the slopes and protect the structures. It's therefore important to appreciate that:

a) the south east corner of the rampart was vulnerable and needed to be supported by the reconstruction of the earth bund to stabilise the scarp slope

b) the land adjacent to the walled patio and greenhouse should be reinstated to help support these structures

c) the back scar of the slope failure to the south of the walled garden has become too steep, thus the movement could regress up the slope and could ultimately damage the southern garden wall: stabilisation is vital.

// THE REMEDIATION WORKS

Our overarching design concept for remediating the slope failures involved providing four key elements, which were implemented as below:

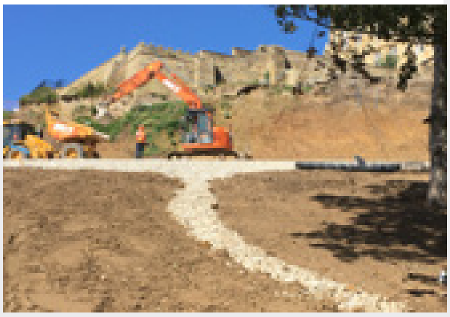
(I) GROUNDWATER CONTROL

Good drainage at every stage of the project was of paramount importance. It was achieved by placing a 1m wide drainage layer behind and beneath the upper reinforced earth wall and connecting it to a series of new counterfort drains running down the slope, through the lower retaining wall and into a collector pipe which discharged off site. In addition, we designed drainage to the rear of the lower retaining wall, which also fed into the collector pipe.

(II) A TOE RETAINING WALL

To stabilise the toe of the slope, we designed a toe retaining wall at a depth of 1m below a 10° slope projected from the adjacent field. Because much of the retaining wall was below the existing ground level, we designed a composite structure comprising a 2m thick concrete foundation with gabion baskets to the rear and a boulder facing.

This retained a good aesthetic and reduced the possibility of water softening at foundation level. We established the height of this wall by ensuring a maximum slope angle of 15° between the top of the wall and a relatively level berm, which formed the base of the reinforced earth wall. These criteria meant that the lower wall is generally 5m in height, increasing to 6m height over a relatively short length.



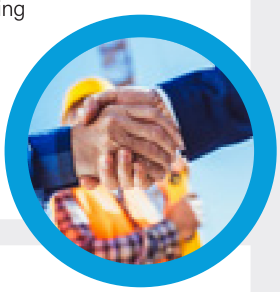
(III) SLOPE STABILITY

The slopes above the retaining wall needed to be sufficiently shallow for long-term stability. The reinforced earth wall was built to approximately 9m in height: it now supports the corner of the rampart and restores access around the foot of the wall.

(IV) A REINFORCED EARTH WALL

This would support the path and ramparts.

The construction drawings were undertaken to our instructions by Rose Consulting Engineers, who also provided guidance on some of the structural issues.



// KEY CHALLENGES

The Castle's insurers instructed HACS Group to undertake the works which began onsite in the week commencing 6th July 2020.

The primary challenge for RGS was to effectively communicate the detailed design philosophy to the contractor, and to make certain that safe working practices were established and maintained throughout the project.

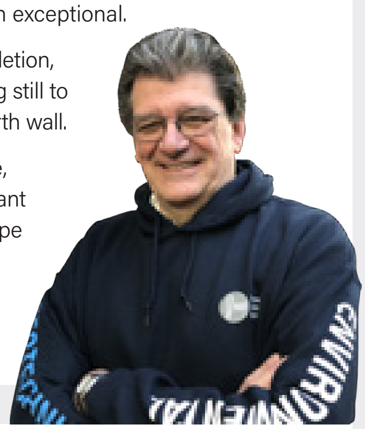
In addition, Rose Consulting Engineers monitored the ramparts every week.

// KIRBY KNOWLE CASTLE - SAFE AND SECURE FOR THE FUTURE

Throughout the remedial works, RGS engineers have visited the site every week to check quality and monitor progress. We should like to stress that the construction works have been undertaken entirely to the satisfaction of **RGS**, **Rose Consulting Engineers** and **David Kempley**. **HACS Group's** performance on site has been exceptional.

Works are now nearing completion, with some topsoil and seeding still to be added to the reinforced earth wall.

When the works are complete, David plans to plant a significant number of trees on the 15° slope between the two retaining structures.



"It is one thing to come up with an optimal remediation, but it's an **absolute pleasure** to see your endeavours brought to fruition by competent contractors. **HACS have been a pleasure to work with.**"

RGS Technical Consultant, **Steve Rogers.**

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