CINTEC

Engineered Micro Cement & Lime Grout Anchor Systems for Earth Retaining & Ground Anchors

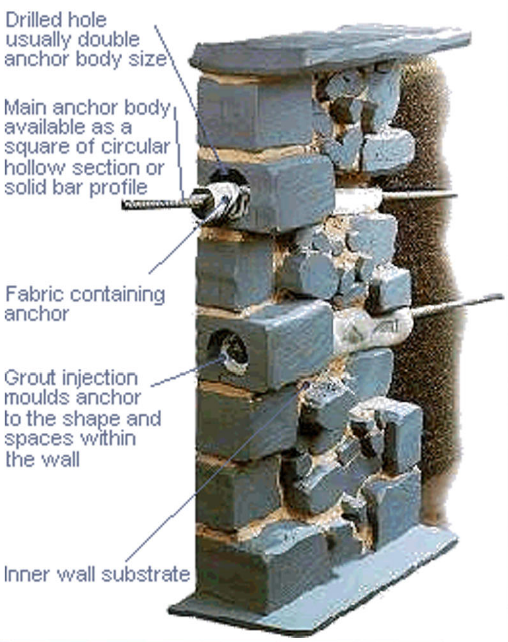
"The Orthopaedic Surgeons for the Construction Industry"

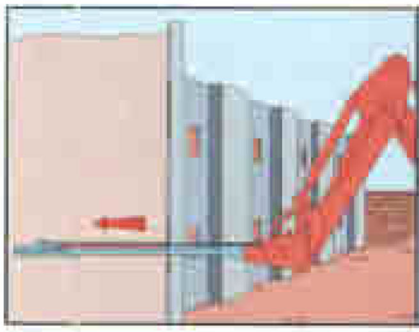
CINTEC
REINFORCEMENT SYSTEMS

Combi-Tec Ground Anchoring

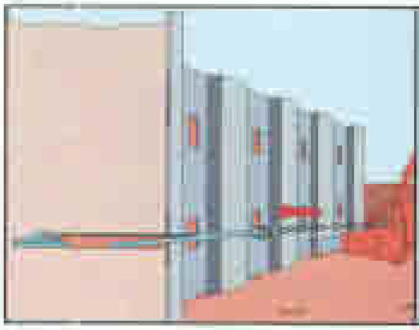
Combi-Tec is a unique system which provides a totally concealed top termination for its Duckbill ground anchors. It enables structures to be effectively and sympathetically stabilised without any visible disturbance to the fabric or the need for unsightly external pattress plates, making it ideal for historic and listed structures.

After coring out or removing a complete brick or stone, the Duckbill anchor is installed and tensioned to its proof load. The Combi-Tec consisting of a stainless steel tube, circular front plate and special polyester sock developed in conjunction with Cintec, is inserted over the anchor bar with the plate sunk below the surface of the masonry. Cementitious grout is injected into the sock under pressure until it has filled all the voids and, having cured, it forms a chemical/mechanical bond within the wall. The anchor is then re-tensioned to its working load and secured against the recessed plate before the fascia core. Brick or stone is replaced and made good to fully conceal the anchor.

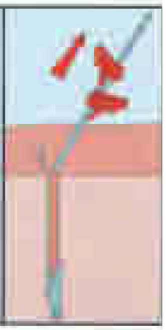


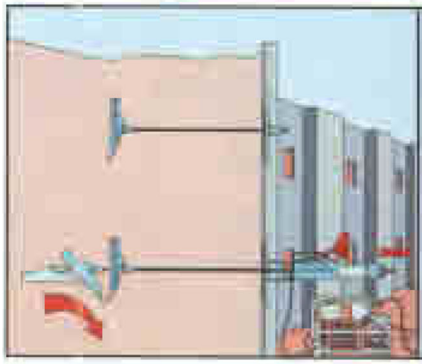


Duckbill anchors are designed to be driven into the ground using hydraulic or pneumatic equipment, with little or no disruption to the structure or surrounding area.

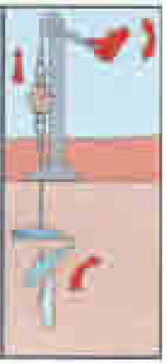


Once the anchor has been driven to the required depth, the drive rod is removed.





A tensile load is applied to the attached tie bar or tendon. This rotates the anchor into the locked position for maximum load holding capacity. The anchor is then proof tested to the designed loading requirements before the top termination is fitted, as specified by the civil or structural engineer.



Hand held

1. Remove stone or brick or core drill clearance hole.

2. Position anchor for installation.

3. Drive in anchor to required depth.

4. Insert Combi-Tec over Duckbill anchor

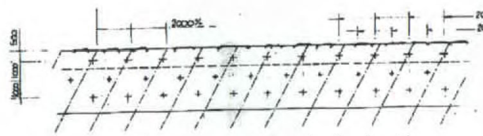
5. Inflate sock by injecting cementitious grout and leave to cure.

6. Tension anchor to working load and secure to recessed front plate with load nut.

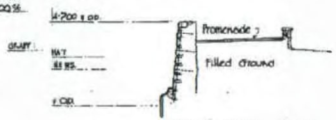
7. Crop excess bar, mortar around Combi-Tec

8. Replace cored material and make good

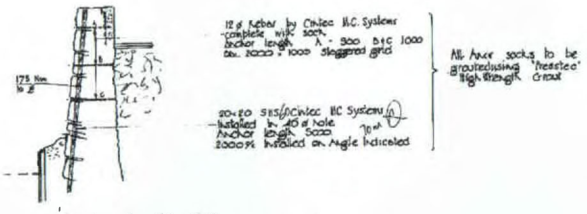
Harbour Wall Ground Anchoring



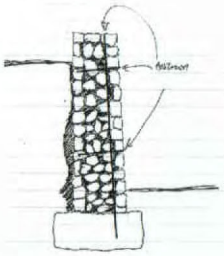
Elevation (Part) indicating proposed Anchor Layout (1:100)

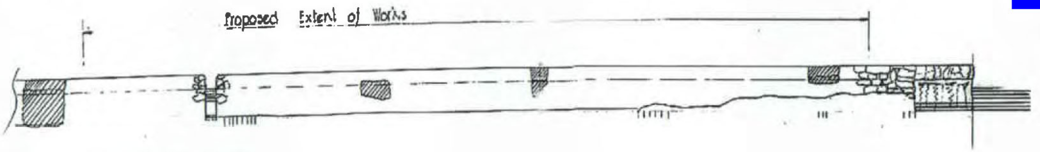


Typical Section (1:100)

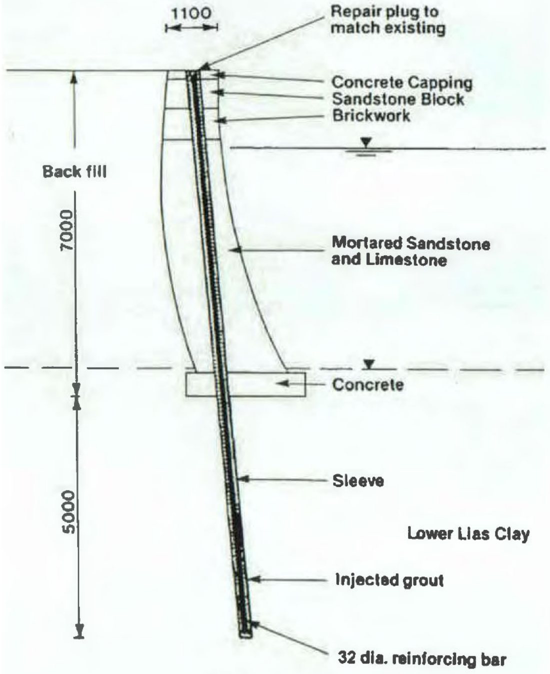


Detail section thro Wall (1:50)





Elevation of Sea Wall (Part) Scale 1:300
Hatched Areas Indicate Masonry Repairs by others



SECTION

STABILISATION OF QUAY WALL

Strengthening of Zeebrugge Harbour Wall (Belgium)

Marco Island Sea Wall - Florida USA

March 1983 - Following a move from Germany to a new home on a Florida island, Civil Engineer Paul Pella was faced with a structural problem common to the region – subsidence and dislocation of the protective sea walls surrounding the homes built upon the island. Fortunately for Mr. Pella, his engineering experiences back in Europe provided him with an innovative new technology   ideally suited f or stabilizing these concrete structures – Cintec Anchors. The ground behind the walls consists essentially of sand, not considered an ideal medium for any form of anchorage. However the adaptability and unique features of the Cintec system overcame any potential difficulties associated with this soil type.

Consisting of a steel rod enclosed in a mesh fabric sleeve, the principle of the system is to inject a specially developed cementitios grout into the restraining sleeve of the anchor and so inflate it along its entire length. As well as providing an extremely strong mechanical bond, some liquid or ‘grout milk’ passes through the material membrane and bonds with the original substraight beyond.

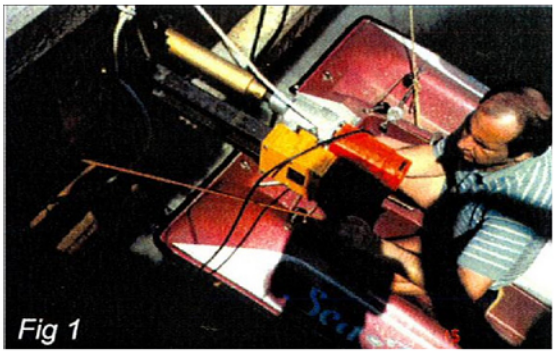


Fig 1

In the case of Marco Island, an additional wide section of expandable sleeve, or sock as it is often called, was attached to the far end of the anchor. When the grout was injected, the additional section expanded to a diameter greater than the rest of the anchor. This created a bulb deep within the soil and ensured a truly secure point of anchorage.


Fig 2

As can be seen in the images (right) the individual boreholes were produced by diamond core drilling, in this case with a core diameter of 65mm (2 ½”) and to the length of the anchor : 3.2 meters (15ft) – Fig 1. The anchors were then installed with a plastic half pipe to facilitate their intsertion – Fig 2. Finally the anchors were injected with ‘presstec’ cementitous grout expanding them from their far end to the front. Although not essential, a flange – plate was laso screwed to the exposed anchor end for additional securement – Fig 3.


Fig 3

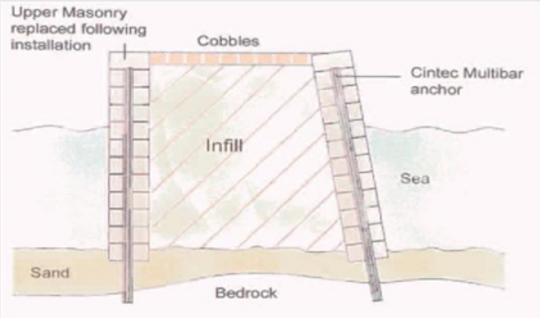
Hay's Dock Lerwick (Shetland Islands) - Scotland

Lerwick is the capital of the Sheltland Islands and in the early 1830's became a thriving centre for the herring industry. The foundation for this commercial success lay with the construction of Hay's Dock and a complex of warehouses and curing yards together with all the facilities for building and rigging sailing vessels. The fortunes of the herring industry fluctuated considerably during the 19th century and as vessels became larger and steam power became the norm, a new larger facility was required and subsequently built by the Lerwick Harbor Trust in 1906. The original dock continued to play an important commercial role adapting primarily to the timber trade.

Panorama of Hay's Dock with the Heritage Centre under construction in the background (right), the restoration of the old sail house on the quay (centre right) and Cintec stabilisation work (end of the quay left of sail house).

Today Hay's Dock stands as a monument to the town's industrial heritage and with the assistance of the Shetland Amenity Trust, Historic Scotland and a contribution of lottery funding, the dock area is being rejuvenated with the construction of the new Shetland Museum and Archives building as well as the refurbishment of the old docks itself.

When originally constructed, technology for building underwater was limited. Consequently the foundations of the furthest and hence deepest part of the quay consist of large stone blocks resting upon a layer of relatively unstable sand and gravel. Inevitably, over the last two centuries, the structure has suffered from significant subsidence.



Consulting Engineers Elliott & Company proposed a solution for installing Cintec anchors to both secure the individual blocks of stone masonry and also to underpin the whole structure to the bedrock below. 18 Cintec Multibar anchors were installed by the drilling contractor Holequest Ltd, each anchor being five meters long and consisting of four strands of 16mm diameter 316 high grade stainless steel rebar in square formation. A drill rig was used to diamond bore each 150mm diameter hole prior to the installation of the mulibar anchors. The two man cycle of drilling and installation proceeded at a rate of one anchor extremely variable weather even in the month of June.

High grade stainless steel was chosen to improve the long term resistance to the corrosive effects of the salt water. Before installation, the polyester sock of each anchor was completely saturated in fresh water, not only to facilitate the injection and inflation of the anchor, but also to provide a temporary barrier between the reinforcing bars and the external sea water. The low pressure injection of the cementitous grout expanded the anchors from the far bedrock end upwards and so displaced any sea water within the drilled holes and locking the anchors were installed, the original surface edge stones and inner cobbles were placed back into position, concealing the stabilisation work beneath.

A mobile rig was employed firstly to core drill the anchor holes, then to temporarily install a metal tube hole lining, following by the lifting and lowering of the Cintec anchor (side) and finally the removal of the temporary core lining prior to anchor injection.

Lock Gates Clarendon Docks, Belfast, U.K.

Cintec anchors have been used to fix two 20 ton lock gates, as part of the 750 million pounds sterling, regeneration of Belfast's Laganside Development.

Clarendon Docks, where shipbuilding in Belfast first commenced, was severely affected by the river's tidal range. Construction of a temporary dam across the existing dock basin, and installation of a lock between the basin and the river, has created an aesthetically pleasing non- tidal water feature capable of facilitating small craft. Although the dock basin was pumped dry for the refurbishment of the waterfront site, it was vital that the fixing method selected was suitable for use underwater.

Each gate is supported by two hinges bolted into the 600mm concrete wall of the lock. One of the key reasons for selecting the Cintec system, was that although the top hinge for each gate is well above the water level, the lower hinge falls within the tidal zone, "explained Brian Campbell. Design engineer for the installers. During the installation, sea-water poured through at one of the anchor locations. We were concerned that alternative fixing methods would not be as successful in such wet conditions."

Following extensive testing, 48 Cintec anchors were embedded into the wall to support the two lock gates. Each lower hinge required 12 fixing anchors, 450mm in length and 102mm in diameter at 200 and 220 centers. The installation of the anchor bolts at the lock gates has been undertaken by ACE Fixings, the approved installers of Cintec anchoring system for Ireland.

Nantgarw Pottery Works Wall - Glamorganshire, South Wales, U.K.

Nantgarw pottery rivaled that of Swansea in the 17th Century for its high quality earthenware, in recognition of its historical importance, the local authority wished to restore one of the now derelict bottle kilns. The location of the proposed rebuild kiln was immediately adjacent to an ancient stone retaining wall. The 2 meter high wall was constructed from random rubble using local stone and was bedded and jointed using black ash mortar. There was concern that this wall would not withstand the additional imposed loading from the rebuilt kiln.

Insertion of 3m Cintec Anchor (left). Its inflation using cementitous grout, (above).

The structural engineers, ove arup working in conjunction with protechahome, opted to specify Cintec ground anchors to stabilize the wall and provide resistance to the additional horizontal forces imposed by the kiln.

Cintec ground anchors were installed horizontally through the bed joints and into the ground infill retained behind it. This infill comprised mainly of broken brick, stone,clay,pottery shards and other assorted material. The core drilling technique employed to create the holes also revealed many voids within it, a significant feature of the Cintec anchor is its ability to bridge such gaps by retaining the flow of grout with its polyester sleeve. The 3 meter long Cintec anchors were installed at 1 meter horizontal intervals and tested to a working load of 15kN each.

The process of diamond drilling (below). With the subsequent core samples produced, (left).

Malmesbury Town Wall

The 12th Century Town Wall at Malmesbury in Wiltshire is being restored as part of an ongoing conservation project involving the Conservation Department of North Wiltshire District Council in conjunction with English Heritage.

The random rubble wall is constructed from locally quarried limestone up to 1.50 metres in thickness, however erosion of adjoining earth and the effects of time had taken their toll resulting in localised delamination and rotation.

In order to maintain the structural integrity of the wall, English Heritage advised the specification of Cintec ground anchors for a number of phases for the work. Stability was returned to the wall by inserting Cintec ground anchors through the thickness of the wall and into the clay and limestone behind.

Diamond drilling (right) and anchor insertions (left).

The anchors were installed through the joints of the stonework following the completion of gravity grouting of extensive voids within. To facilitate this process clay was used to seal the open jpints between the stones in order to retain the original historic grouting. This was later removed and the wall pointed with lime mortar to match the original material. The Cintec ground anchors were tested to a working load of 15kN. Other, smaller Cintec anchors were also used for wall consolidation.

CINTEC

TEST CERTIFICATE

Load - Start	Time Held	Load - End	Extension	Extension
2	2 Mins.	2		
4	2 Mins.	3.75		
6	2 Mins.	6		
8	2 Mins.	8		
10	2 Mins.	10		
12	5 Mins.	12		
14	2 Mins.	14		

Test Date: 20/08/97
Install date: 06/08/97
Type of Test: Tensile loading

Anchor Type
20 x 20 x 4000mm

Site Address
Malmesbury
Malmesbury Town Wall

Embedment Depth
1000mm

Bore Hole Diameter
40mm

Company Name:
Quicksons

Engineers Name:
John Avent

Anchor Location
Top Right Section

Base Material
Clay/Rubble

Required Load
12 Kn

Company Address:
Unit 1
Whiteway Court
Cirencester
Gloucesterhire

Engineers Address:
Mann Williams
4 Palace Yard Mews
Bath
BA1 2N11

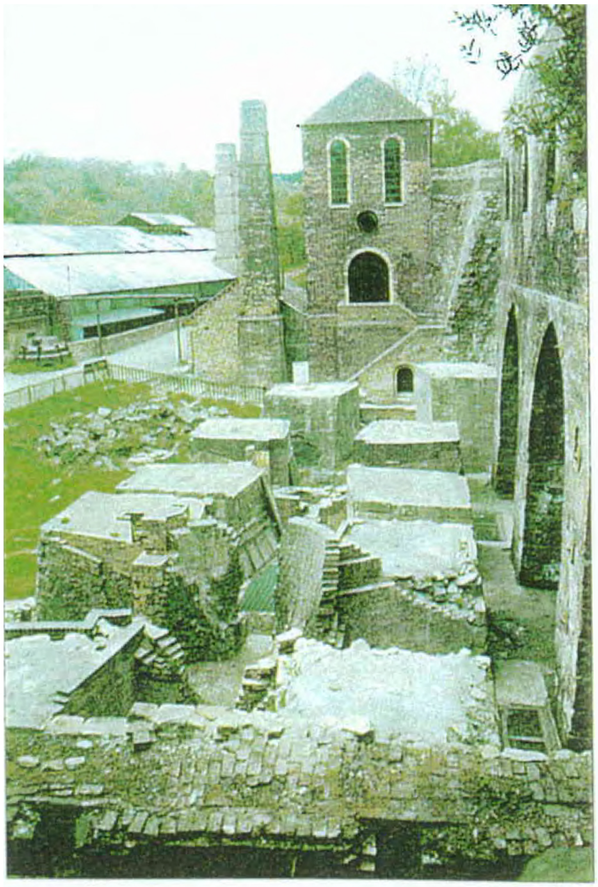
Comments
Initial drop in load due to bedding in' against a clay embankment

Grout Type
Presstec standard

Anchor Material
Stainless Steel

Persons Present	Company	Position	
Dennis Lee	Cintec International Limited	Technical Advisor	
John Brooks	Cintec International Limited	Area Sales Manager	
Andy	Minerva Stone Conservation	Foreman	

The restoration and stabilization of the Blists Hill Furnaces



Mark Goring, Barnsley Associates Limited, Consulting Civil and Structural Engineers, discusses the restoration programme that is helping to preserve a historic site.

The restoration and stabilization of the Blists Hill Furnaces

Mark Goring, Barnsley Associates Limited, Consulting Civil and Structural Engineers, discusses the restoration programme that is helping to preserve a historic site.

Introduction

The repair and restoration of the Blists Hill Furnaces, which form part of the Blists Hill Open Air Museum Site near Ironbridge, Telford, has recently been completed. The works were instigated as part of a major repairs programme designed to renovate, and restore, numerous structures within the Ironbridge Gorge Heritage site.

A detailed repair schedule was prepared for each of the sites by a working party, including architects, civil and structural engineers, surveyors and archaeologists and the work funded by the Department of the Environment.

The purpose of the repair work was to restore and renovate the properties and structures to an acceptable condition whereby the ownership and future maintenance of the structures would pass into the care of Ironbridge (Telford) Heritage Foundation.

In order to bring about the restoration and stabilisation of the Blists Hill Furnaces, it was necessary to undertake remedial work on the existing brickwork and stonework, together with the introduction of extensive ground anchors and tie bars.

Work required to prevent further ingress of surface ground water into the furnaces was undertaken as a separate, but integral, phase of the works.

Background history

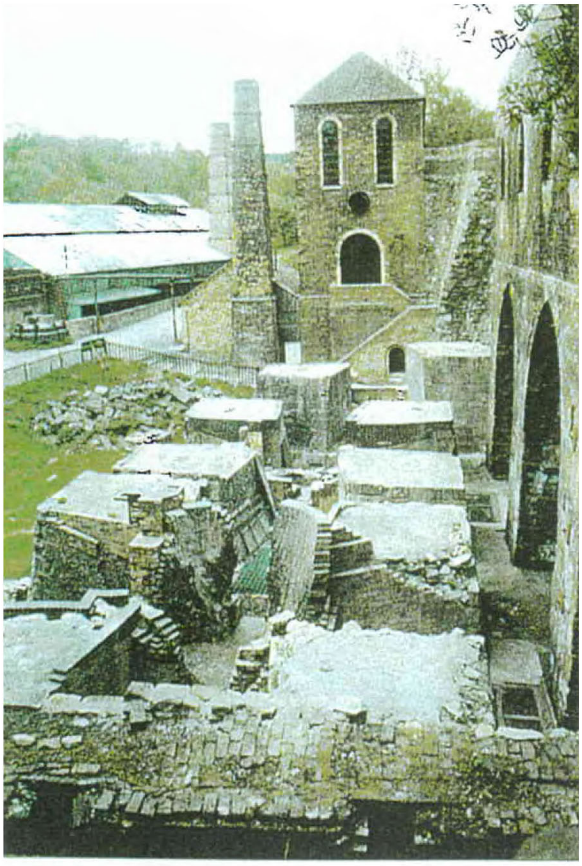
The Madeley Wood Company was formed in 1756 when the ironworks at Bedlam, one mile west of Blists Hill, on the River Severn, was founded. The Bedlam Furnaces were owned by this company, which held mineral leases in Madeley Parish, enabling it to extract coal and iron ore. Upon its opening in 1790, the company had access to the Shropshire Canal, the Blists Hill section of which ran immediately to the east of the Blists Hill works site. Proximity of raw materials and the means of transporting the finished product persuaded the company to build a blast furnace at Blists Hill in 1832.

Additional furnaces were added in 1840 and 1844, making a total of three, and the site remained active in the production of pig iron until 1912 when the ironworks ceased production, following the blowing in of two of the furnaces.

The site history through the 20th century is less well documented. Dense vegetation cover was allowed to establish itself amongst the ruins until the late 1950s when the site was subject to spoil dumping, which completely buried the furnace bases. In the 1970s the Ironbridge Gorge Museum Trust began clearing and restoring the works.

Structural defects

The buildings had fallen into poor repair due to the ravages of time and the ingress of ground water. This dereliction and general instability of the furnace structures represented a hazard to the preparation of a specification for the repair. It was, therefore, necessary to undertake the design and installation of an extensive scaffold propping scheme to enable the facade of the structure to be stabilised sufficiently to enable the appraisal and detailing of repair work.



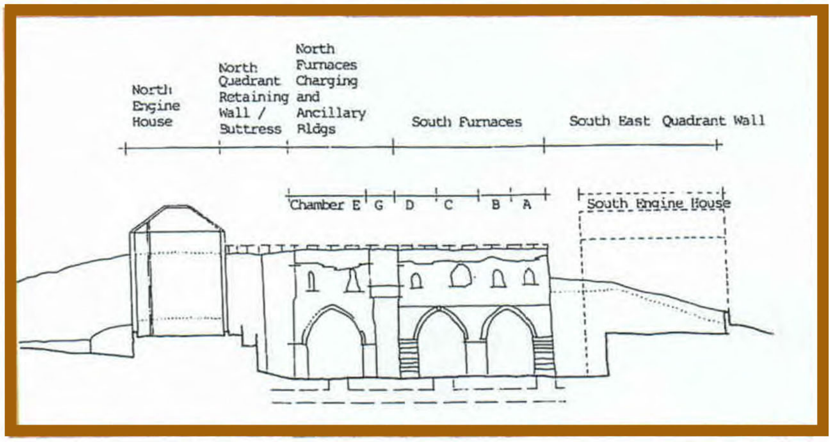
Blists Hill Furnaces' structure was originally built in 1832, with additional furnaces being added in 1840 and 1844.

The scale of works was restricted due to the nature, historical and archaeological importance of the site. Problems were encountered during the design stage of the scheme due to the presence of many underground tunnels and chambers which linked the furnace bases back to the main engine houses.

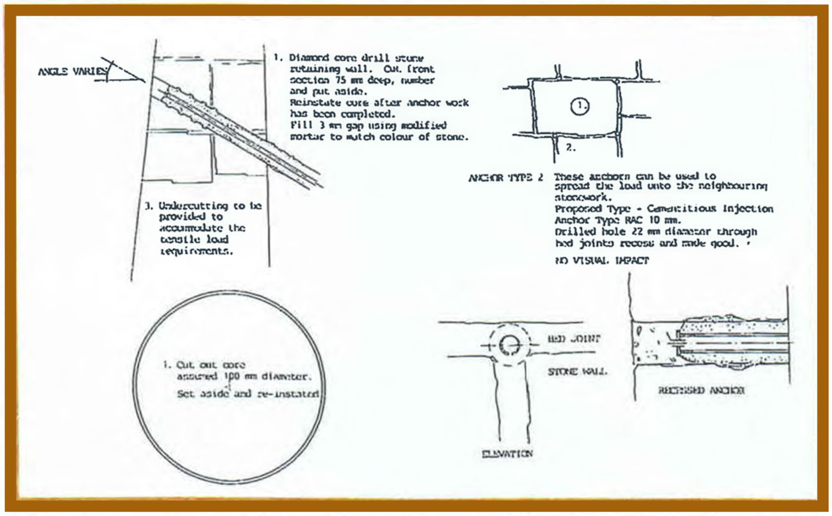
By buttressing the supporting scaffolding back onto the old furnace bases, and utilising heavy concrete blocks as kentledge, sufficient dead weight was applied to stabilise the temporary propping. Prior strengthening of the furnace bases was required to ensure that the high loads from the buttresses could be transferred to the sub-strata without distressing the superstructure.

Following completion of the propping scheme a detailed visual and photographic inspection of the site structures was undertaken to ascertain and record the condition of the walls and to determine, the cause of the damage, enabling the formulation of a repair and stabilisation strategy. This appraisal concluded that the damage which had occurred could be generally summarised as follows:

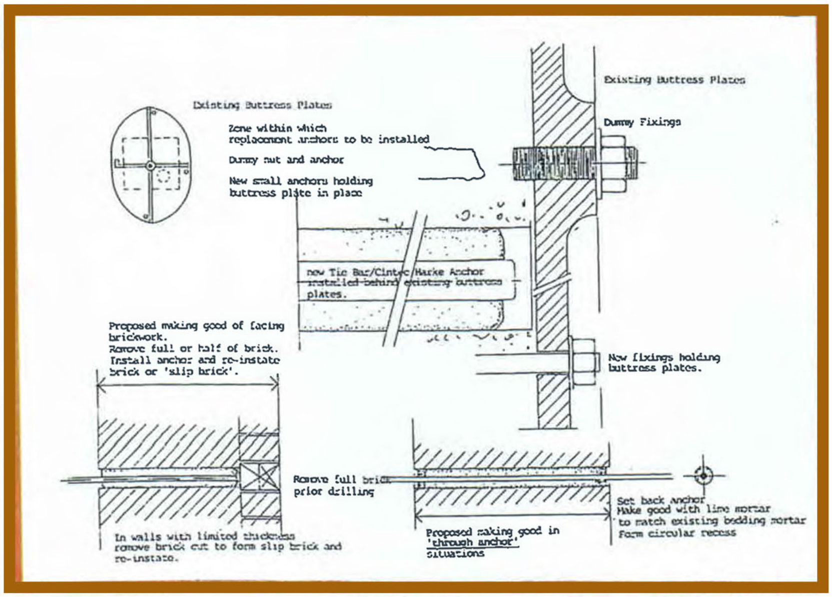
- Superficial damage of the masonry and stone walls caused by the presence of vegetation and water ingress. This was most evident at the top of the structure, where significant loosening of the brick and stonework had occurred with subsequent loss of the retained material. Water penetration, in conjunction with frost action, was also causing significant deterioration to the fabric of the brickwork and stonework.



West elevation.



Making good anchor holes in stonework.



Making good anchor holes in brickwork.

- Differential settlement in the south wall of the south furnace charging building resulting in westward rotation of part of the wall and consequent vertical and diagonal cracking through the superstructure supported by it.
- Cracking and spreading movements in the superstructure, resulting in outward displacement of walls.
- Distress cracking, loss of material and localised collapse of the stone masonry retaining walls which where up to 13 m high.

The geology of the retained ground was investigated, using shell and auger holes with subsequent laboratory tests to determine the characteristics of the subsoils. The investigation concluded that the site is overlain with topsoil on fill materials from 6 - 11 m deep. The fill is principally ash containing one or more of brick and tile discards, blast furnace slag and coal. It is deposited on mudstones containing strata or lenses of sandstone and hard clay. The mudstone at the fill interface is frequently softened to a medium clay due to weathering caused by the presence of ground water.

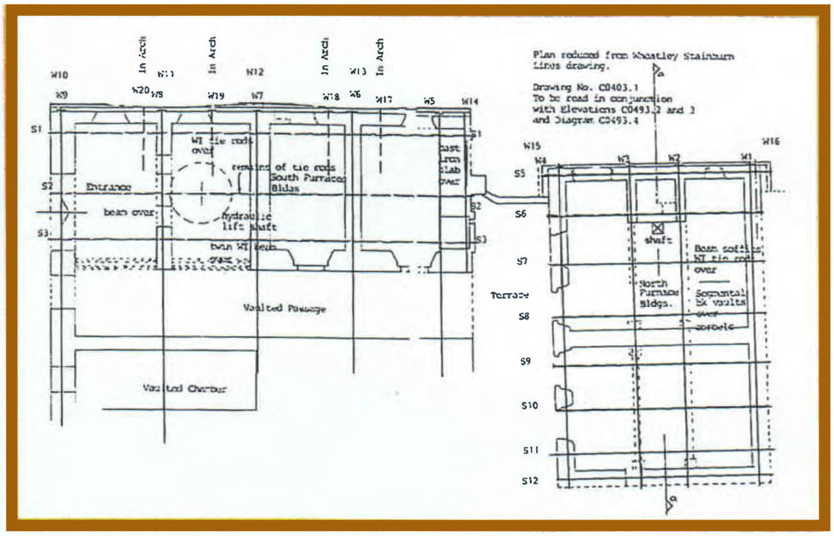
Rates of deformation and crack development

Since the excavation of the structure in 1980, a number of structural movements appear to have taken place, as evidenced by cracking and distortion of early repairs undertaken by the Ironbridge Gorge Museum Trust. No long term records exist, but during the preparation of reports for the repairs brief, it was visibly noticeable that movement and cracking was worsening, confirming that it was progressive.

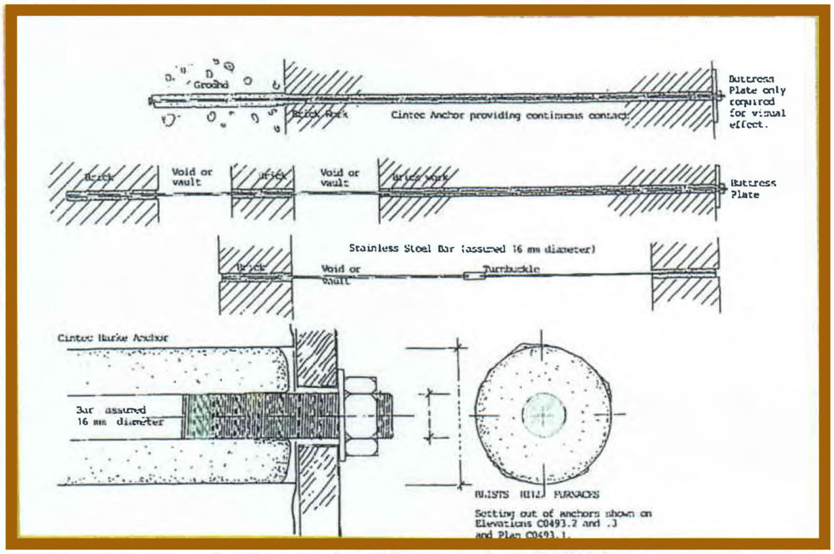
In addition to this cracking, rusting of the cast and wrought iron plates, lintels and tie bars within the structure was continuing, due to the ingress of ground water, with a consequent splitting and heaving of masonry. This in turn caused increased water penetration to the structure.

Remedial measures

Following detailed discussions with English Heritage a series of remedial measures to stabilise the structures was proposed. This work included the general consolidation of voided and eroded brickwork and stonework in conjunction with the installation of new tie bars and ground anchors. The selection of the ground anchor and tie bar was the subject of careful consideration, due to the very significant



Setting out anchor/tie bars.



Application of tie bar system with Cintec Harke anchors covering the south and north furnaces and north engine house.

archaeological and historical importance of the structure.

Concern was expressed that any grout used in the anchoring works should not be allowed to penetrate areas of the structure in an uncontrolled fashion. Many anchor types and systems were reviewed, but the Cintec Harke Anchor, manufactured by Cavity Lock Systems Limited, was finally adopted. This provided not only the correct structural solution to the problems but also enabled the work to be undertaken in a controlled manner, with the grout restricted to only those areas around the anchors where it was structurally required.

The Cintec Harke anchors were used to replace the eroded and rusted tie bars, in addition to their use for the ground anchorage work on the project.

Careful consideration and planning was undertaken by the design team in conjunction with the specialist sub-contractor so that the all the anchors and ties were installed with minimal visual disturbance to the building structure, not only during installation but also upon completion of the work. The ground anchors were required to sustain a maximum safe working load of 60 kN and this was achieved by socketing the Cintec Anchors a minimum of 3.0 m into the mudstone strata.

The ground anchor installation required a 100 mm diameter core to be taken out of the centre of a selected stone within the retaining wall. Drilling was then undertaken with or without a steel casing, using an air flush drilling system, to a designed anchor position and length of embedment into the underlying mudstone. The anchors were installed at a downward angle in order to reduce the depth of drilling necessary to penetrate the mudstone. Even with this angular adjustment the length of the Cintec Anchors was in excess of 20 m. The Cintec anchor was then inserted in the hole with the sock positioned around the anchor. The whole anchor was then pressure grouted to within 100 mm of the face of the wall. Finally the original core was refitted into the core hole and resined into position so as to mask the end of the anchor.

Where necessary, due to the location of the anchor within the wall and the adjacent stones, the insertion of small diameter stainless steel needles, secured by epoxy resin was undertaken. This 'stitched' the area around the anchor together. Generally a Cintec RAC 10 mm diameter anchor was employed with the anchors positioned into the bed joints of the stone retaining wall. In most cases 5 Cintec RAC anchors were installed around each ground anchor position.

Within the south and north furnaces where vault tie bars were to be replaced, the use of the Cintec Harke anchors was once again adopted.

The new ties were inserted adjacent to the locations of the existing tie bars with the existing patress plates initially removed to enable drilling to take place.

The anchors were installed in 50 mm diameter holes cored through the brickwork and where necessary into the mudstone strata behind the structure. The anchors and socks were inserted and grouted within the brickwork/mudstone, leaving the exposed areas of tie bar clear of any grout.

The existing patress plates were re-fixed in their existing position so as to mask the repair works and leave the structural appearance of the building apparently unaltered.

Conclusions

The use of the Cintec Harke sleeved anchors has enabled the stabilisation and renovation of this very important archaeological and historical structure to be achieved. The anchors were able to satisfy the necessary structural criteria whilst enabling all the operations to be fully controlled, thus producing only a nominal visual and archaeological impact on the structure which remained apparently unaltered.

Acknowledgments

1. **The Ironbridge Gorge Museum Trust**
   Archaeological Unit
2. **W.T. Specialist Contracts Limited**
   Sub-Contractor
3. **Weaver Construction Limited**
   Main Contractor
4. **Wheatley Taylor Stainburn Lines**
   Architects

Department of Intercity Railways, British Rail
Railway Bridge 325 Abington/Carlisle Railway

Ground Anchor Stabilization

Cintec Ground Anchor Installation at bridge 325 Abington

INTRODUCTION:

Cintec International Ltd has developed a system of ground anchors incorporating the patented grout techniques utilised in the Cintec System of anchor fixings. The bridge section of the Civil Engineering Department of Intercity Railways, British Rail, permitted the installation of trail ground anchors through the abutments of bridge number 325 on the Edinburgh / Carlisle Railway line for testing.

GENERAL DESCRIPTION:

In general terms the anchors have the following features:

a) A high tensile steel bar (ribbed type 2) forming the central element and load transferral mechanism to the abutment wall.

b) The reinforcement bar has been epoxy coated to provide the first layer of corrosion resistance in accordance with British Standard for Ground Anchors BS8081: 1989.

c) The corrugated sleeve of UPVC forms the second barrier against moisture and therefore corrosion resistance. The corrugations form a shear key to permit the transfer of forces from the ground to the central bar and then back to the structure.

d) The elements in a,b and c above are within a polyester fabric sock which expands to contain the pressurised grout, the sock becomes formed to the shape of the cored or drilled hole. Plastic centralisers are used to ensure the correct positioning of the corrugation relative to the bar. Drawings and sketches are attached showing details.

e) The grout forms the interlocking mechanism between the steel bar and the grout interface. The grout is a patented formulation developed specifically for anchor applications, it is delivered under pressure and is designed to obtain compressive strength capabilities of between 40 – 50 N/mm^2. Shrinkage is avoided by the use of additives premixed with the grout. The grout itself, being cementitious provides a highly alkaline protective environment against potential corrosion of the steel and the passage of moisture in the unstressed areas.

f) The sock arrangement used in the trial anchors has features such that the remote end (that which is in contact with the soil) can be inflated independently of the near sock (that which is contact with the structure). With this arrangement the remote end was tested in order to establish the load capabilities. After testing the outer sock was inflated to form the bond with the abutment structure.

g) Relatively low steel stresses were involved in the anchor testing to eliminate unnecessary elastic extension and subsequential relaxation losses may be neglected.

h) The outer sock forms a secure bond with the abutment structure thus avoiding the need for unsightly anchor heads visible on the outside.

i) Each stage of the inflation process is monitored by a 'check sock', that is a small sock that inflates at the external end of the anchor indicating that the remote or unseen sock is fully inflated.

The anchor component parts and design with regard to corrosion resistance comply with the requirements of BS8081: 1989 the British Standard for Ground Anchorage for Permanent Anchors.

INSTALLATION:

From a scaffolded access platform, a mining barrel was used to core the hole through the abutment structure and into the embankment behind. The anchors were inclined at 20° to the horizontal beneath the bridge structure, and at 30° to the horizontal at wing wall locations. The anchors were inserted into the preformed holes and the two sections of the inner sock inflated. The grout is inserted at pressure from a pressurised container (89 PSI, 0.61 N/mm^2). The outer sock was not inflated in order that each of the anchors could be subsequently be test loaded.

Sufficient time was permitted for the cementitious grout to cure before any load testing operations were carried out.

GROUND CONDITIONS:

The abutments are located either side of a vehicular access route through the railway embankment. The embankment was built approximately 100 years ago from nearby materials and consisted of gravel, sands with clay and silt. Given the soil profile found, the behaviour of the anchors would inevitably be unpredictable and large resultant test loadings were not anticipated.

TESTING:

The testing was carried out using a hydraulic jack with a calibrated dial gauge measuring the tensile load applied in tonnes. Each of the anchors was tested with the resulting loads tabulated in the following tables. The loads were applied in 4 tonne increments with a minimum of 10 minutes between each rise in the load. Several of the anchors were left for extended periods at the higher loads which coincided with the limit of the testing equipment. One anchor number 2 with the load applied overnight to see if any slippage had occurred. A small relaxation was apparent, although it could not be established if this was due to anchor creep or the testing apparatus deflecting.
The location of anchors is indicated in drawing C2162/Sk 1.

The results obtained were of larger magnitude than could have been anticipated given the actual ground conditions. In general the loads obtained varied between 13 – 20 tonnes. The bond stress or cohesion at the soil / interface has been calculated to vary between 81.3 and 219.7 KN/m^2. Anchor number 1 has an unusually low value of 93.8 KN/m^2, however this particular hole was left exposed for some considerable time after the mining barrel was removed before the anchors were fitted due to an equipment malfunction which may have led to some localised collapse of the substrate. Anchor number 5 also has an unusually low bond stress of 81.3 KN/m^2, this anchor was inserted into the area of the sloping embankment, which would not have had the benefit of the loading consolidation as the area underneath the railway tracks. The remaining results varied between 140.6 to a maximum of 219.7 KN/m^2 which reflects the variable nature of the substrate.

As the sock is inflated under pressure with grout, it expands to fill the shape of the hole, thus filling any irregularities in shape and size. A combination of different factors is anticipated to develop the load capacities obtained as follows.

1) Forming an irregular wedge by the shape of the hole and sock inflation, thus creating the need to shear the soil in order for the anchor to fail.
2) The grout 'milk' extrudes through the sock and partially bonds to the surrounding granular material, thus enlarging the effective diameter of the anchor.
3) Localised compaction of the surrounding material due to the pressurised grout inflation.

The installation and testing was witnessed by:

Mr Kader of British Rail Intercity Civil Engineering Dept.
Mr Barnet of British Rail Intercity Civil Engineering Dept
Mr Dimmick of Cavity Lock Systems (now Cintec International).
Mr Parry of Cavity Lock Systems (now Cintec International).
Mr Woodhouse of Fordham: Johns Partnership.

The anchors were installed in the period February – May 1992 and tested between June 1992 and December 1992.

DESIGN OF ANCHORS:

The following outlines the basic principals involved in assessing the design parameters and considerations in relation to the capacity of the ground anchors.

STEEL TENDON

The steel tendon in the anchors tested comprised of a high tensile steel bar, (epoxy coated for protection).

The bar area was established by the formula: $\text{Area required} = \dfrac{\text{Load}}{\text{Fy}}$

Where:- Load = working load multiplied by an appropriate factor of safety (200Kn)
Fy = characteristic strength of the steel (460 N/mm^2).

For the test anchors, the area required = $\dfrac{200 \times 10^3}{460} = 434.8\ \text{mm}^2$

Bar diameter 40mm provides area of 1256 mm^2, F.O.S. = 2.88
Bar diameter 32mm provides area of 804 mm^2, F.O.S. = 1.85

The steel stresses in this case were maintained at the low levels shown in order to avoid significant elastic extensions and therefore potential relaxation losses.
The steel bar utilised in the tests was a high yield ribbed bar (type 2) which has raised ribs on the surface for increased bond capability.

The bond between the grout and the bar can be established from the equation:-

$Fbu = B\sqrt{fcu}$ where fbu = the design ultimate anchorage bond stress.

$Fbu = 0.7\sqrt{40}$ B = coefficient dependent on type (0.5 x 1.4 = 0.7)

$= 4.43\ \text{N/mm}^2$ fcu = compressive strength of grout (40 N/mm^2)

DESIGN OF FIXED ANCHOR LENGTH:

The pull out capacity of the test anchors can be shown as:- $\text{Tf} = \pi\,\text{D L S}$

Where S = the shear, bond and skin friction at Substrate/rock interface (Kn/mm^2)

D = diameter of fixed anchor (m)

L = Length of fixed anchor (m)

Tf = pull out capacity in (Kn)

The values of S varied between 81.3 to 219.7 Kn/m^2. For design purposes the lowest value should be used and a factor of safety of 4 utilised to limit ground creep in permanent anchors.

For design of anchors at specific locations the nature and behaviour of the substrate must be established by testing. Full-scale load tests are recommended to confirm laboratory results.

FIXED ANCHOR DESIGN IN ROCK

$$\text{Tf} = \frac{\pi\,\text{D L Tult}}{\text{Factor of Safety}}$$

Where Tult = the ultimate bond or skin friction at sock / rock interface.

The value of Tult will vary dependant on rock type, condition and discontinuities. A minimum fixed anchor length of 3m is recommended to account for local variations and a factor of safety of 3 to 4 be applied dependent upon the circumstances of usage.

FIXED ANCHOR DESIGN IN COHESIONLESS SOILS

The substrate at the testing location falls into this category although clay and silts were present.

$$\text{Tf} = \frac{\pi\,\text{D L S}}{\text{Factor of Safety}}$$

The value of S must be found by testing. A factor of safety of 4 should be used and a minimum length of 4m is recommended.

FIXED ANCHOR DESIGN IN COHESIVE SOILS

$$\text{Tf} = \frac{\pi\,\text{D L}\,\alpha\,\text{Cu}}{\text{Factor of Safety}}$$

Where α = adhesion factor 0.3 – 0.45 verified by testing.
Cu = average undrained shear strength of substrate.

The value α and Cu must be found by laboratory tests or full-scale tests. The factor of safety should be of the order of 3 to 4 and a minimum length of 3m is recommended dependent upon consistency.

ANCHOR BOND TO STRUCTURE

Should the anchor be required to bond to the structure (as opposed to an anchor head arrangement) the following equation may be used:-

$$\text{Ts} = \frac{\pi\,\text{D L B}}{\text{Factor of Safety}}$$

Where Ts = ultimate bond to the structure material (Kn)

B = bond between sock and structure (Kn/m^2)

The value of B will vary dependent upon material, values of 600Kn/m^2 are reasonable (subject to testing) for solid concrete or masonry.

DISCUSSION

The general conditions at each location will dictate the design stresses to be used in assessing the ultimate capacity of an individual anchor. Where laboratory tests are not available, full-scale insitu tests are required to establish the lower bounds of the substrate capacity.

A minimum fixed anchor length of three metres is recommended to account for local variables in substrate conditions.

In order to reduce the possibilty of long term ground creep, factors of safety should be applied. These factors should be of the order of 3 to 4 dependent on soil consistency, life expectancy and their importance to the structure.

The fixed anchor length must be located beyond the critical zone, such as the wedge failure, slip circle, rock discontinuities in order to be effective. The free anchor length will depend upon the geometry of the location.

The anchors can act as a restraint, only accepting load if movement occurs, or they can be pre-stressed to a set load to provide an active force.

A feature of the Cintec System is that a choice of connections can be achieved with regard to fixing to structure. Traditional anchor head details may be used where periodic re-stressing or monitoring is required. Where the structure is suitable, the anchor may be bonded to the material as a permanent fixing, without the requirement for surface apparatus.

GENERAL DESIGN CONSIDERATIONS

Where ground anchors are being utilised, careful consideration should be given by the designer to the following points:-

a) Detailed field and laboratory tests to establish soil characteristics.
b) Full-scale load tests to confirm laboratory predictions.
c) Assessment of consequences of potential long-term creep.
d) Overall length of anchor, fixed anchor length, failure planes.
e) Effects of anchor groups if anchors closely spaced.
f) Likely stress losses due to tendon relaxation.
g) The free anchor length can be released from the grout by use of smooth tubes forming the second barrier of corrosion resistance, thus avoiding stressing ground close to structure.
h) The factor of safety to be applied.
i) Reference should be applied to the British Standard BS.8081 : 1989 or other appropriate document for advice on usage and design.

CONCLUSION

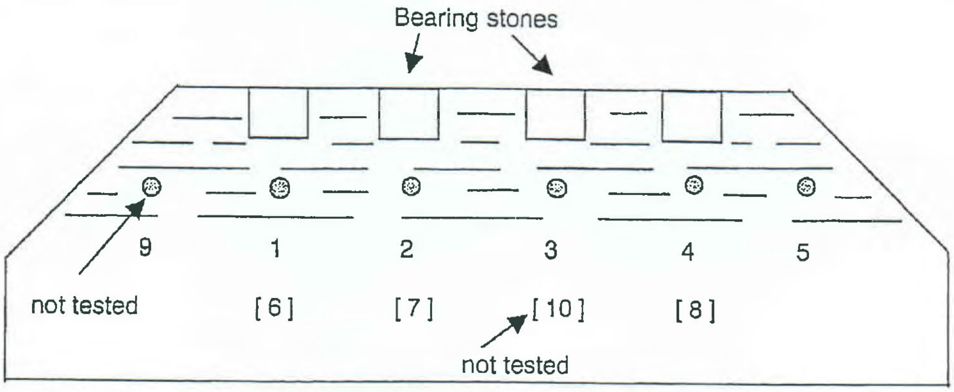
The testing of the ground anchors showed that the Cintec System could be successfully used in even the most difficult of ground conditions and achieve results in excess of expectations.

Careful appraisal of all factors must be given by the designer, to the points raised in the design considerations section, in order to fully realize the potential of the system.

S. WOODHOUSE B. Eng (Hons) C.Eng M.I.Struct.E.

23rd APRIL 1993

Date: April 1993 Scale: / Drawing No: C2162/Sk 1
Drawn: J.S. Design S.W. Project: BRIDGE 325, ABINGDON
Drawing Title: GROUND ANCHOR DETAIL TO ABUTMENTS



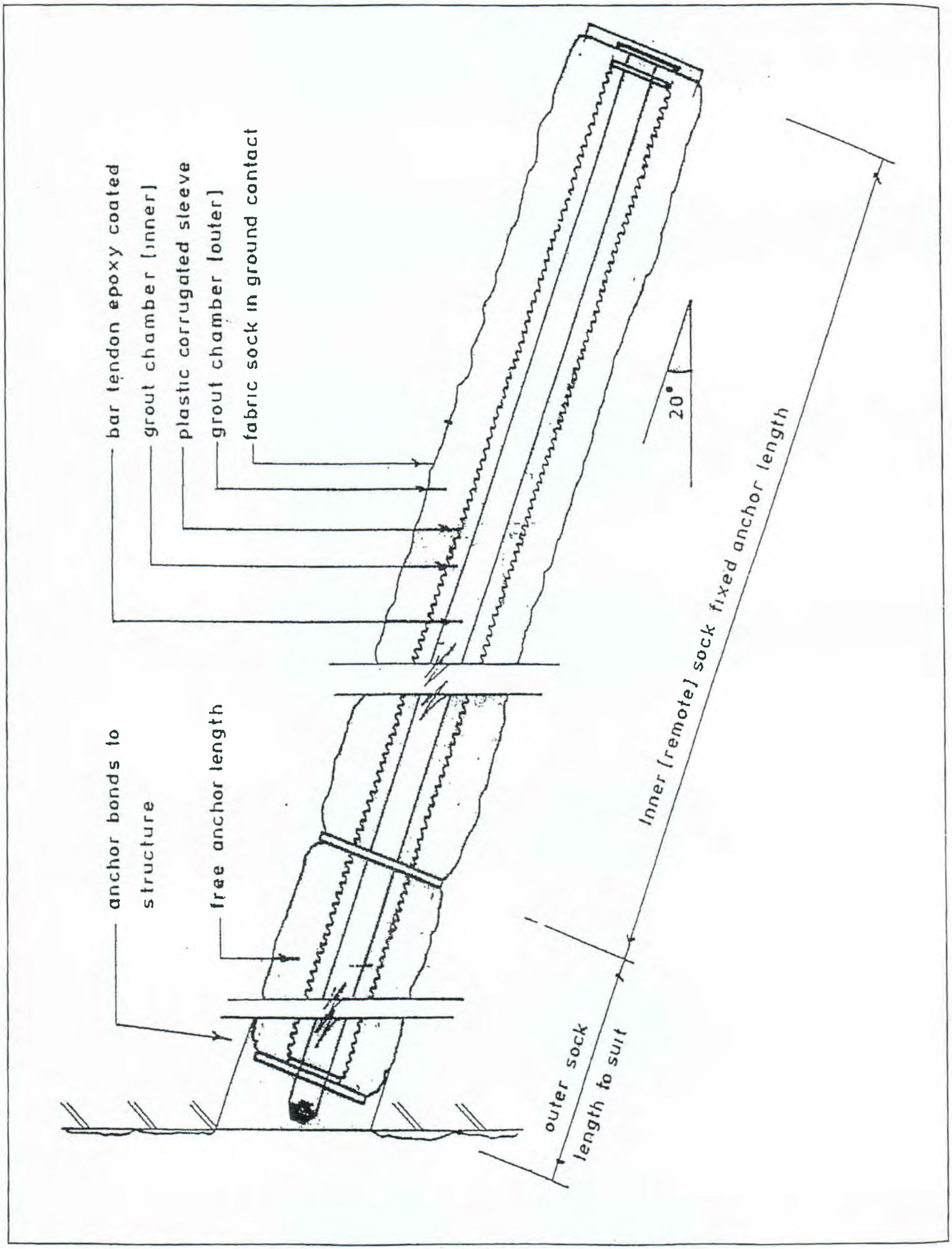
ELEVATION OF NORTH & SOUTH ABUTMENT SHOWING GROUND ANCHORS
SOUTHERN ANCHORS 1 – 5
NORTHERN ANCHORS 6 - 8

ANCHOR NUMBER	ANGLE OF INCLINATION	TOTAL LENGTH (M)	FIXED ANCHOR LENGTH OR LENGTH OF EMBEDMENT (M)	HOLE DIAMETER (MM)	TEST LOAD [T]
1	20°	5.45	4.1	124	15
2	20°	3.95	2.6	124	18
3	20°	3.45	2.1	124	18
4	20°	3.95	2.6	124	19
5	30°	5.45	4.1	124	13
6	20°	4.45	3.1	124	18
7	20°	4.45	3.1	124	17
8	20°	4.95	3.6	124	20

Date: April 1993 Scale: / Drawing No: C2162/Sk 3
Drawn: J.S. Design S.W. Project: BRIDGE 325, ABINGDON
Drawing Title: GROUND ANCHOR TEST RESULTS

Anchor number	Angle of inclination	Total Length (m)	Fixed anchor length or length of embedment (m)	Hole diameter (mm)	Soil anchor Interface (mm ²)	Test Load (T)	Test Load (KN)	Shear stress Soil / anchor Interface (N/mm²)	Shear stress soil anchor interface (KN/m²)
1	20°	5.45	4.1	124	1.599x10^6	15	150	0.0938	93.8
2	20°	3.95	2.6	124	1.014 x10^6	18	180	0.1775	177.5
3	20°	3.45	2.1	124	0.819 x10^6	18	180	0.2197	219.7
4	20°	3.95	2.6	124	1.014 x10^6	19	190	0.1873	187.3
5	30°	5.45	4.1	124	1.599 x10^6	13	130	0.0813	81.3
6	20°	4.45	3.1	124	1.209 x10^6	18	180	0.1488	148.8
7	20°	4.45	3.1	124	1.209 x10^6	17	170	0.1406	140.6
8	20°	4.95	3.6	124	1.404 x10^6	20	200	0.1424	142.4

Date:	April 1993	Scale:	/	Drawing No:	C2162/Sk 2
Drawn:	J.S.	Design S.W.		Project:	BRIDGE 325, ABINGDON
Drawing Title:	GROUND ANCHOR DETAILS				



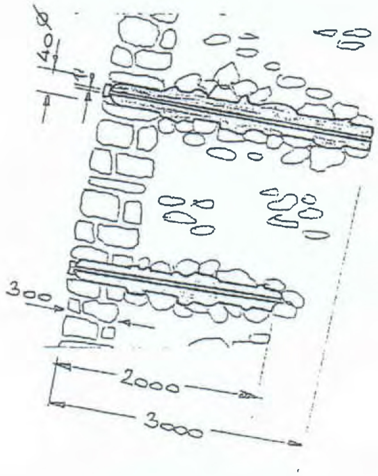
Installation of Ground Anchors Through Railway Bridge Abutment

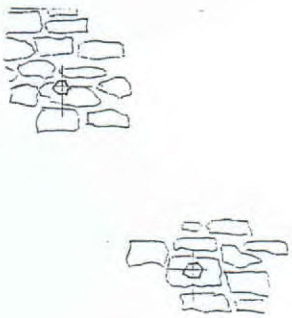
Proposed *CINTEC* stitching anchors during restoration 1995

Obj. Wülzburg

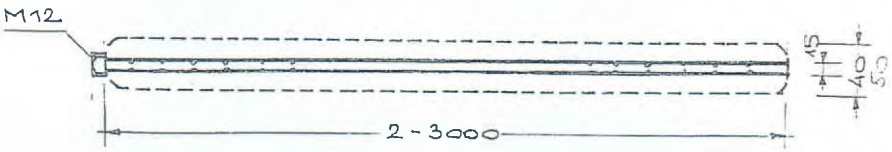
STÜTZWAND SCHNITT TEILANSICHT

Darstellung
unmaßstäblich

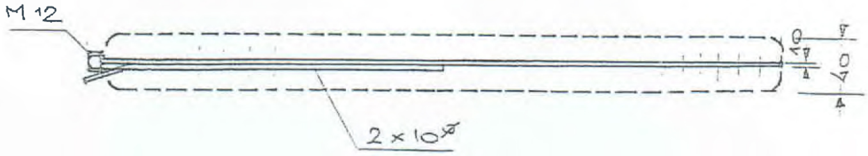




SCHNITT durch STANDARDANKER System C=INTEC-MC



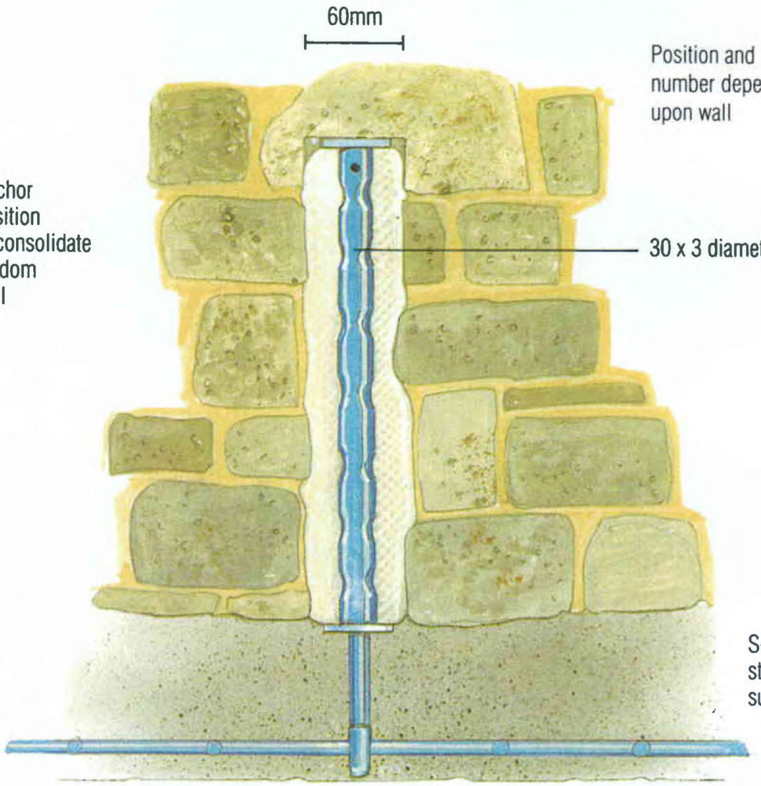
SCHNITT durch DOPPELROHRANKER System C=INTEC-MC
Ausführung RAC 10 X 1 mm.



STITCHING ANCHOR APPLICATION

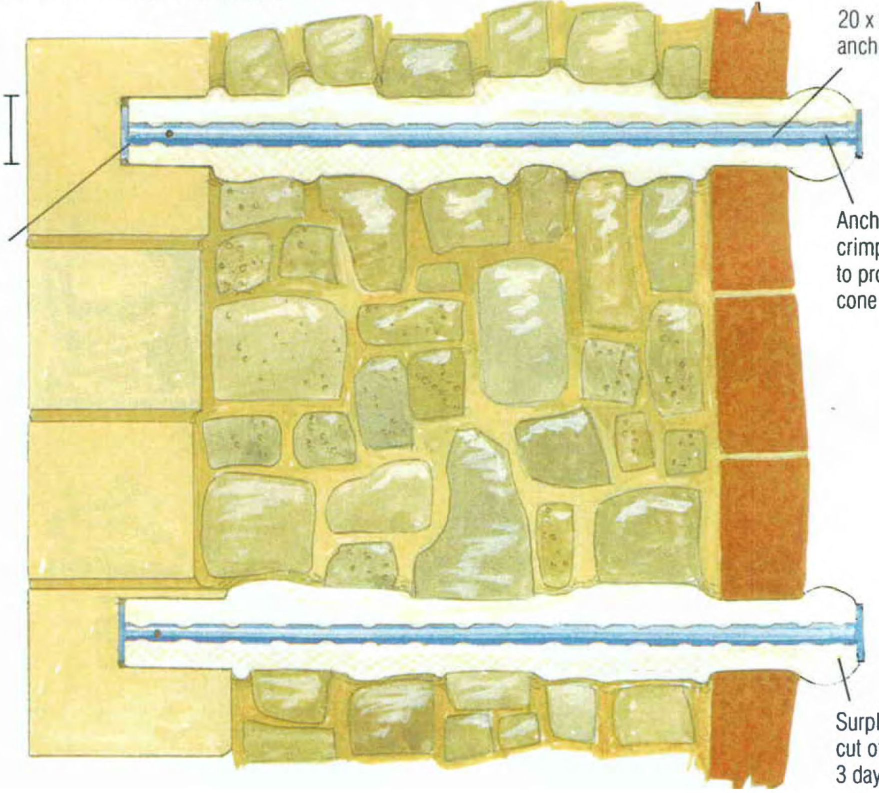
TYPE RCT

Typical Consolidation of Random Rubble Wall



Section – Plan

Typical detail of random wall consolidation using circular hollow section to overcome difficulties that arise when the wall is badly deformed and avoid the need to have differing anchor lengths



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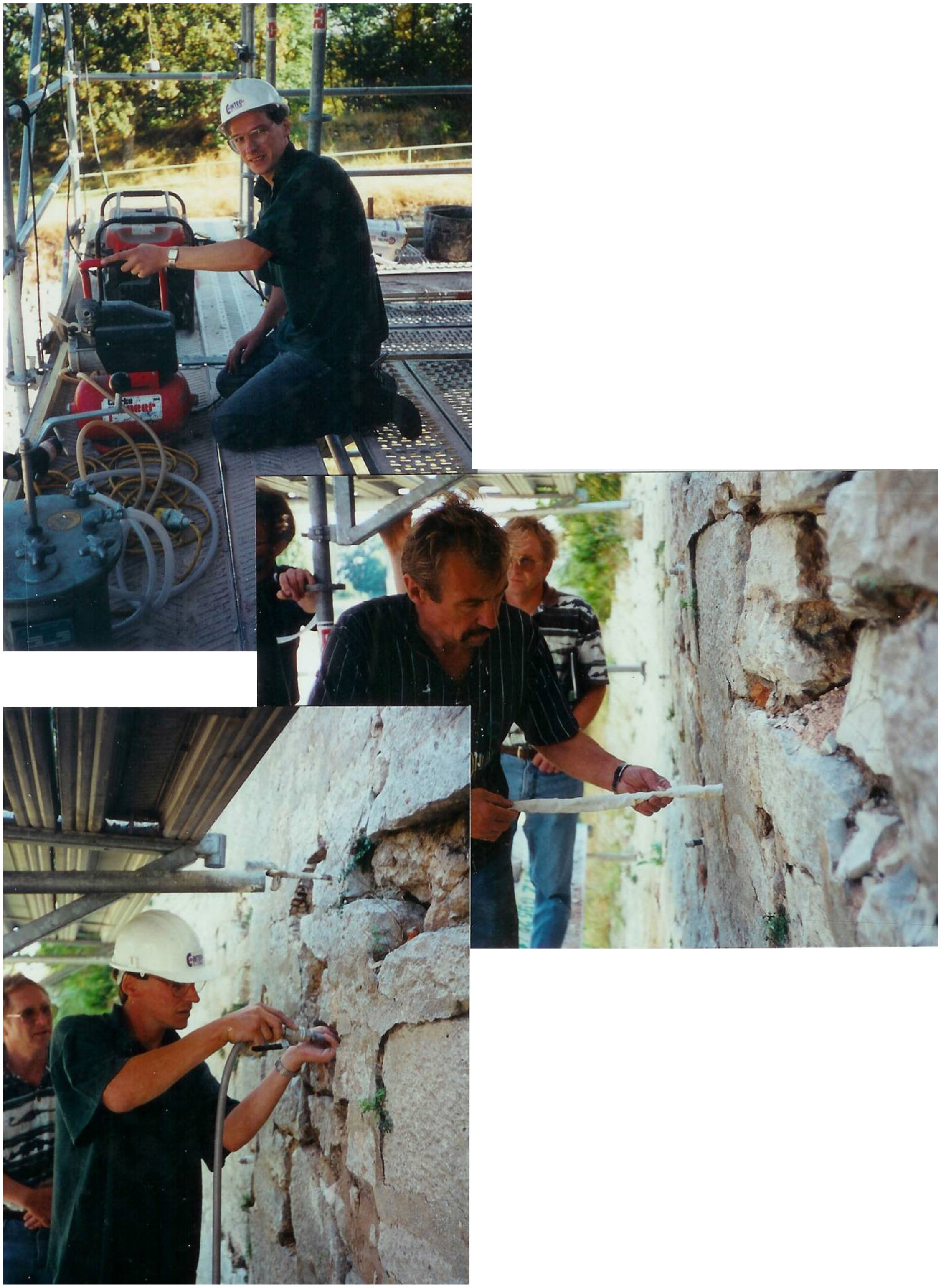
CINTEC tools, stitching anchor installation & injection



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Corner, drilling for small stitching anchors, Grout mix

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Holy Austin Rock - Kniver, Staffs, England, UK

Restoration of the lower cave dwellings at Holy Austin Rock, Kniver Edge

External view of main entrance to restored dwelling.

Internal view of front room, above cave.

The name 'Holy Austin' is said to be after a hermit who lived near the site during the 16th century. This is the earliest known reference to the occupation at Holy Austin rock.

In May 1993 the National Trust completed the first phase of restoration in their imaginative scheme to restore the nationally important cave dwellings at Kinver Edge, Staffordshire. Since the rock houses were cleared of their last occupants, as late as the 1950's, the rock structures had deteriorated and several of the caves within the three-level complex of up to a dozen separate dwellings had become dangerous. In 1990, the Trust took a bold decision to re-build the upper rock houses and to bring the interior up to modern standards for a Custodian to control the area immediately around Holy Austin Rock.

The Lower Caves were still a serious structural concern. They had been crudely bricked up by the local Council in the 1950's for public safety, as there had been extensive rock falls from the ceiling of the large central cave – an amazing tunnel known in later years as the Ballroom.

With the financial support of the local Management Committee, the national Trust once again commissioned the Architect for work to secure the Lower Caves, and also to restore the facades and one or two of the rooms to their original design.

The unstable condition of the soft red Permian sandstone required careful and often dangerous work inside the caves by the Contractor, G T Wall and Sons of Stourbridge, to secure the falling ceiling slabs.

A major structural defect, resulting from the internal failures, was the large vertical fissure and associated cracks, just behind the eastern façade, which had widened in recent years due to weathering and root penetration. The structural Engineers, Ascough and Associates, say the danger of the whole façade falling outwards, as a 1 m thick slab, and it was decided to use modern rock bolting techniques to anchor this slab back to the stabilized rock including the new foam concrete fill, just above cave ceiling level.

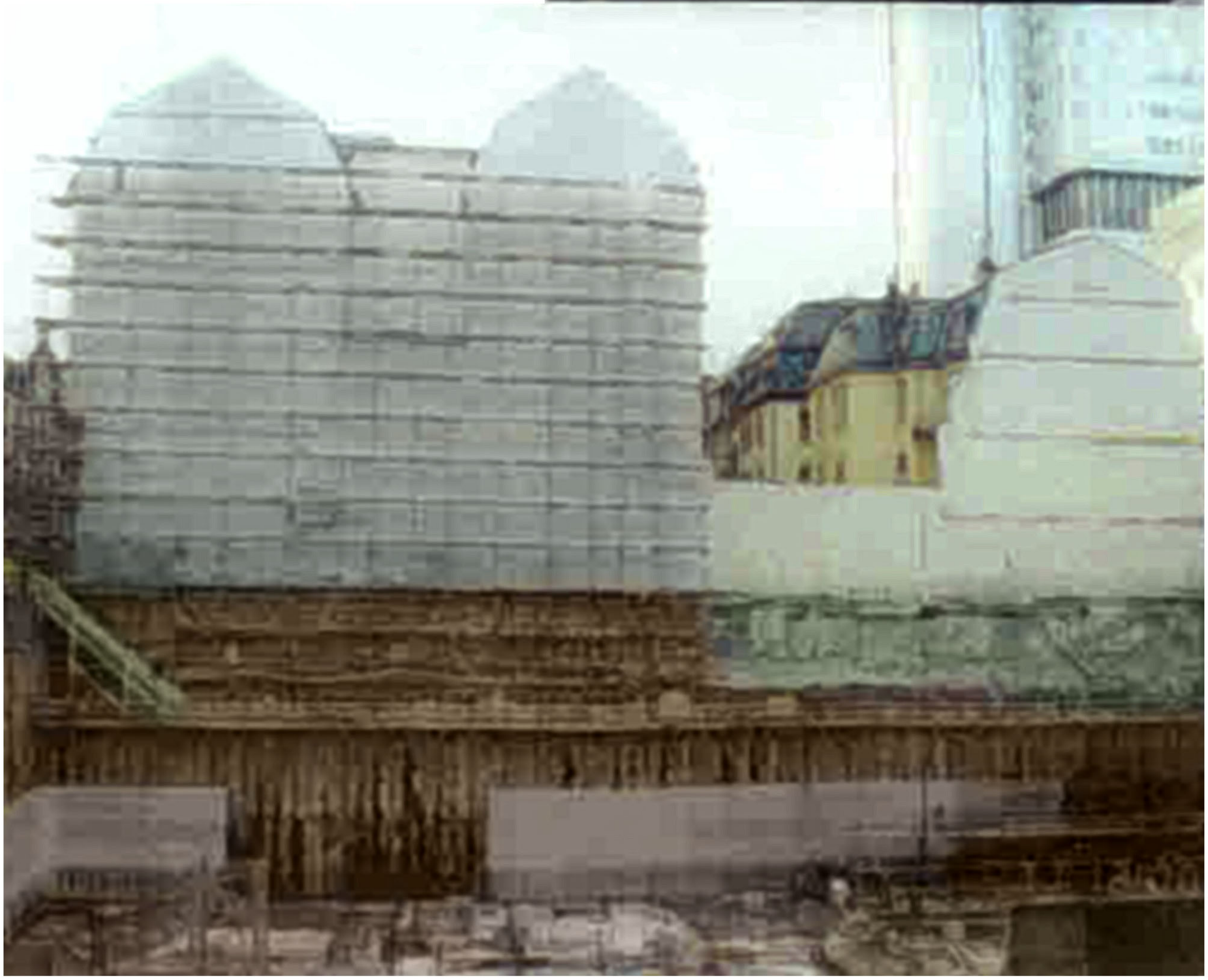
The drilling and grouting of the rock anchors was carried out by A.P.B. Group Limited of Stoke-on-Trent in August 1997. The Specification was for 5 Cintec rock anchors 3-4m long, and 20mm diameter, 316 grade stainless steel rebar. The anchors were grouted into 40mm – 50mm diameter holes drilled with air flush rotary rock drills. In addition to the main rock bolts, several more ceiling bolts were installed under the Engineer's direction using 16mm diameter anchors of varying lengths.

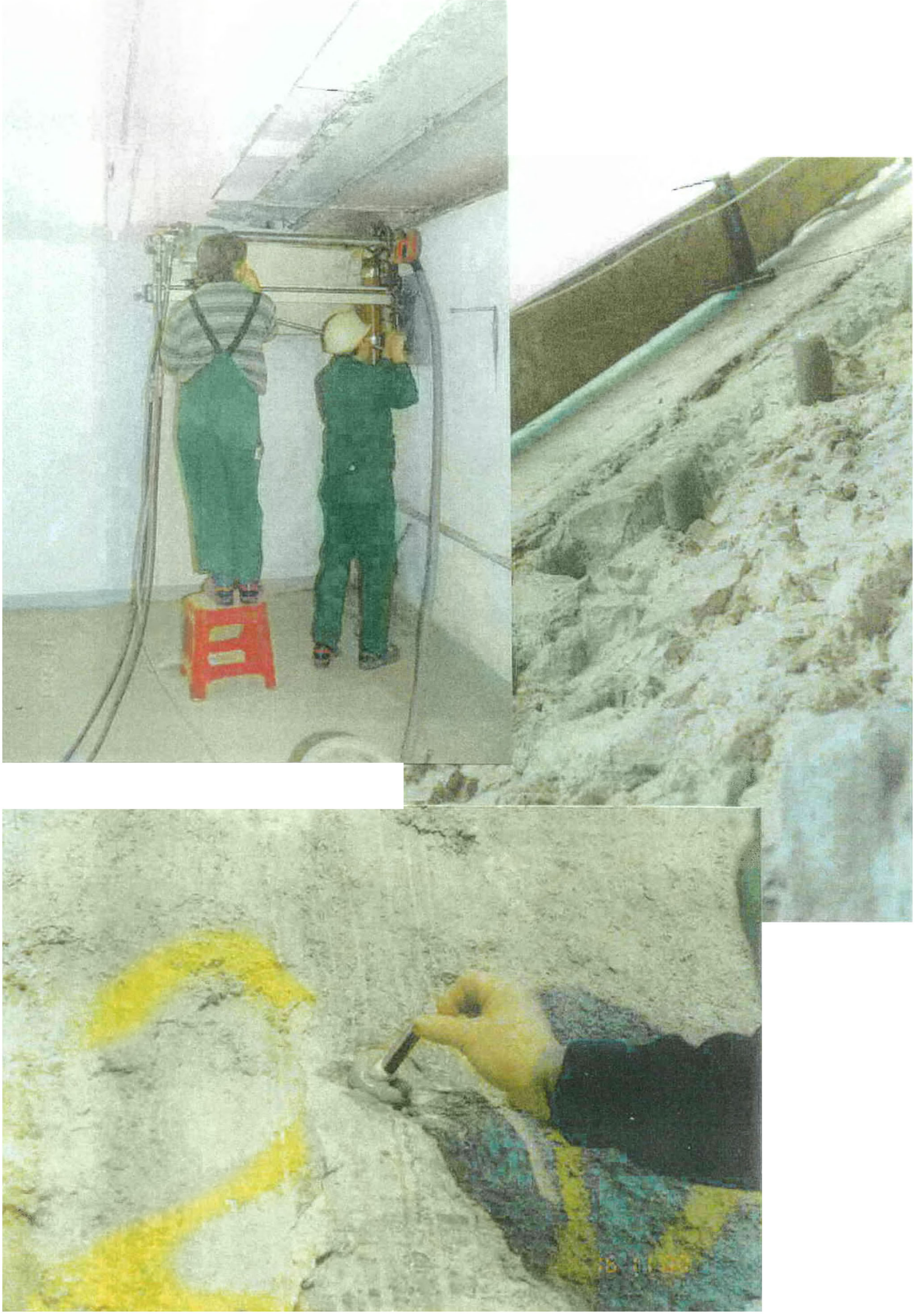
The Lower Caves were completed in November 1997 and the National Trust has now raised the status of the caves giving them a detailed entry in the National Trust handbook.

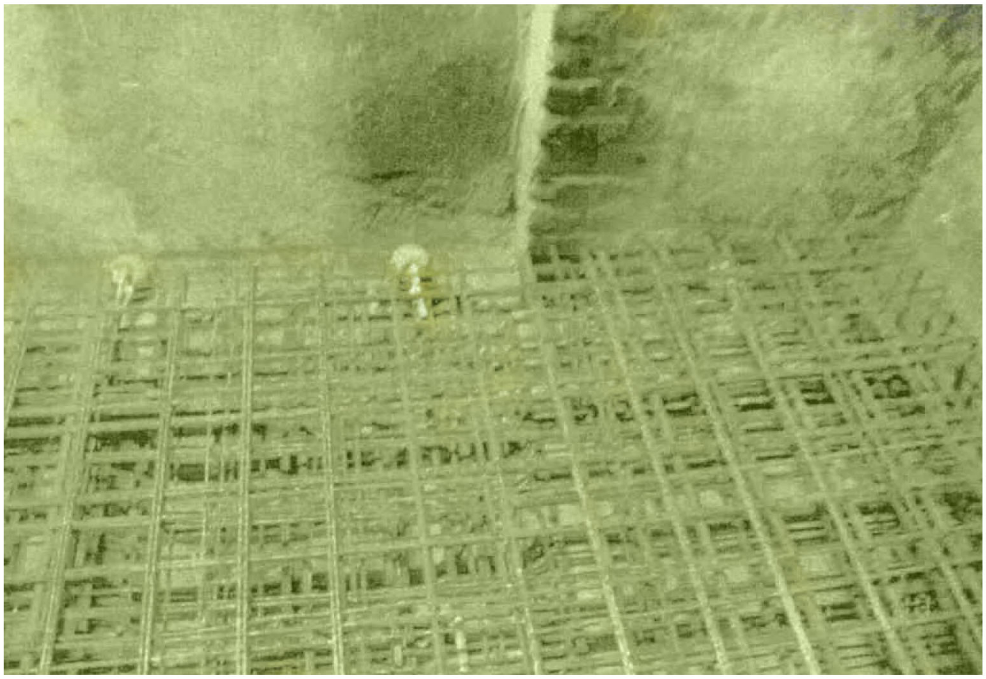
Adjacent caves in unrestored condition.

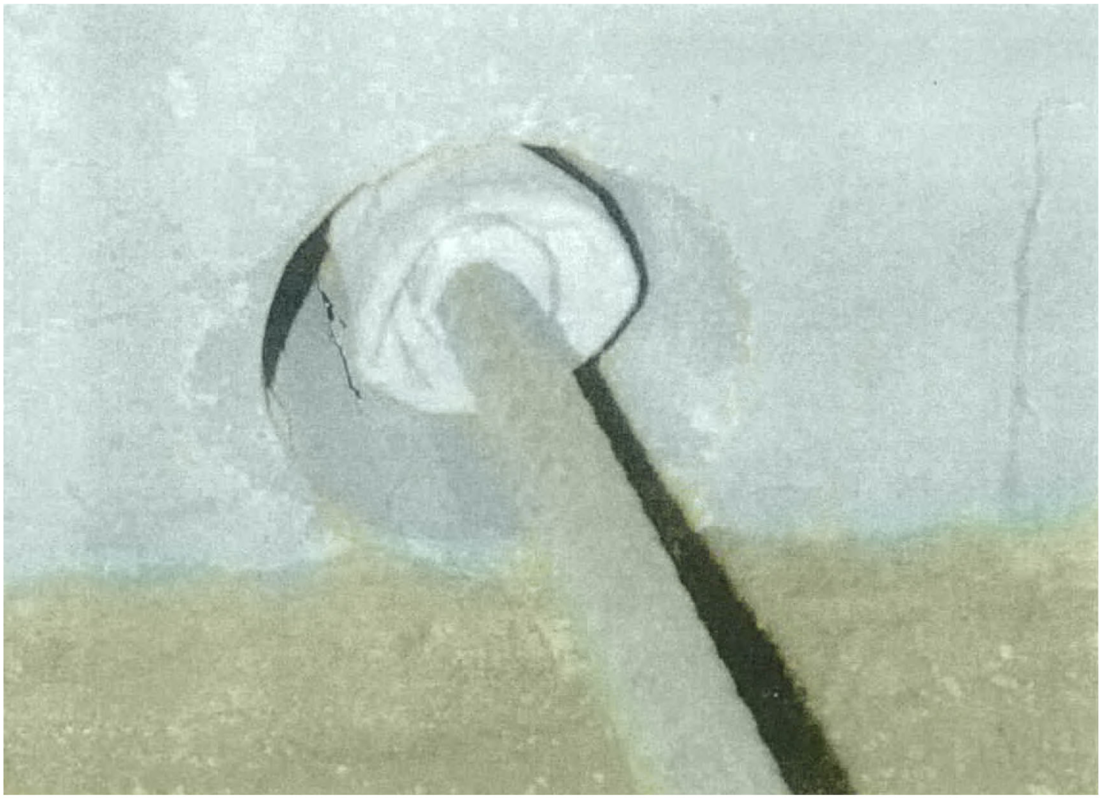
Roof bolt support to ballroom ceiling.

The completed row of cave dwelings ready for occupancy.









CINTEC

The Strengthening and Stabilisation of Masonry Retaining Walls
by Cintec North America

Masonry Retaining Walls:

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Masonry Retaining Walls:

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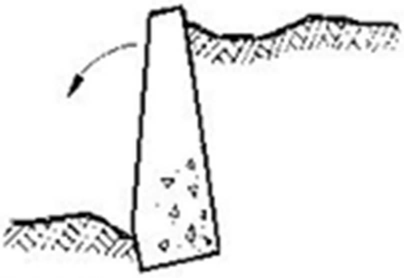
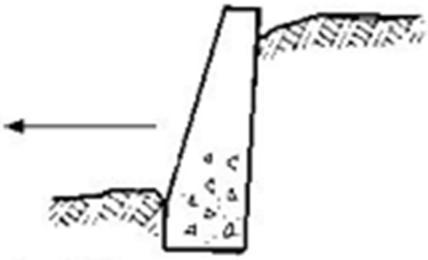
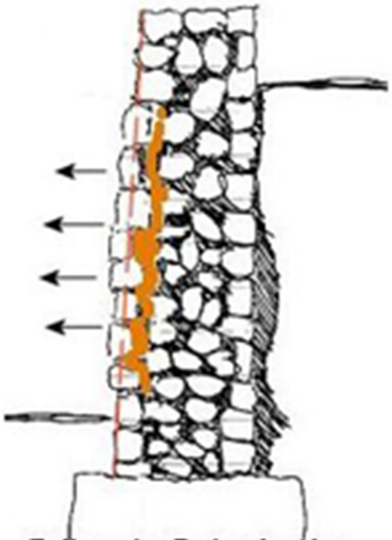
Deep seated failure



Failure by Rotation



Failure by Sliding



Failure by Delamination

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Investigative cores are taken to determine the wall thickness,
type of material within the wall and the consistency of the retained material.
This will enable a design to be established regarding the location of the Cintec ground anchors.

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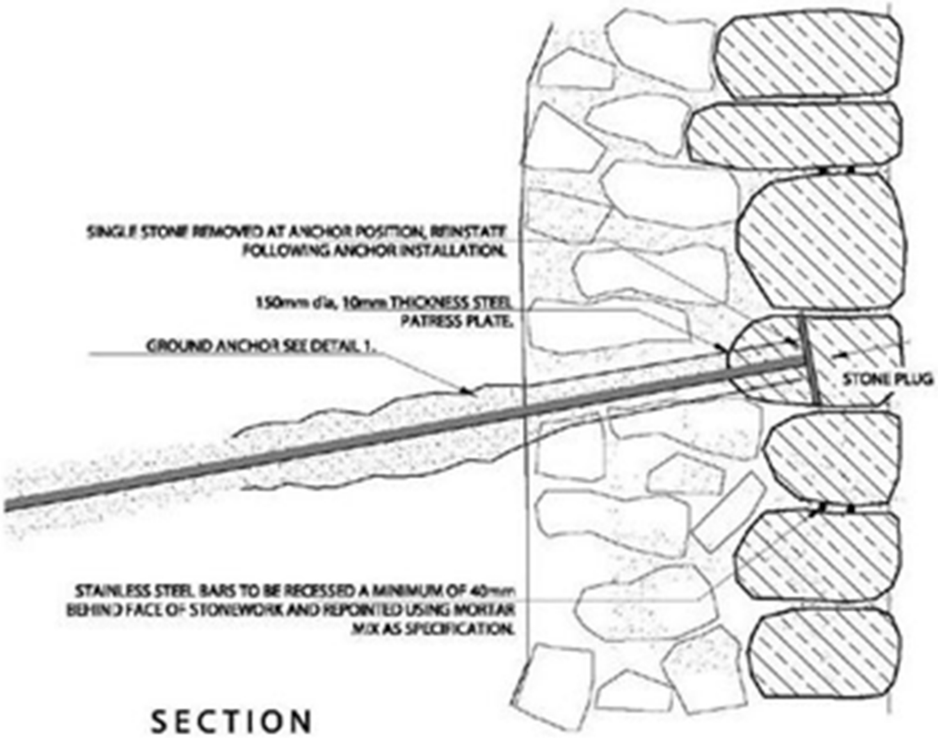
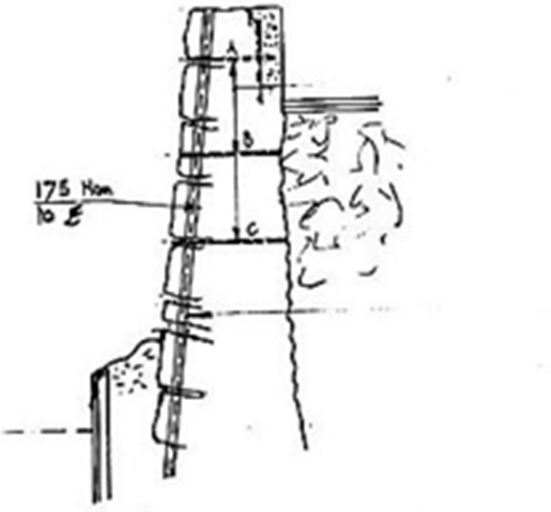


SECTION



Detail section thro Wall (1:50)

GENERAL DESIGN CONSIDERATIONS

Where ground anchors are being utilised, careful consideration should be given by the designer to the following points:-

a) Detailed field and laboratory tests to establish soil characteristics.

b) Full-scale load tests to confirm laboratory predictions.

c) Assessment of consequences of potential long-term creep.

d) Overall length of anchor, fixed anchor length, failure planes.

e) Effects of anchor groups if anchors closely spaced

f) Likely stress losses due to tendon relaxation.

g) The free anchor length can be released from the grout by use of smooth tubes forming the second barrier of corrosion resistance, thus avoiding stressing ground close to structure.

h) The factor of safety to be applied.

i) Reference should be applied to the British Standard BS.8081 : 1989 or other appropriate document for advice on usage and design.

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IN-SITU LOAD TESTING THE CINTEC GROUND ANCHOR

A feature of the Cintec System is that a choice of connections can be achieved with regard to fixing to structure. Traditional anchor head details may be used where periodic re-stressing or monitoring is required.Where the structure is suitable, the anchor may be bonded to thematerial as a permanent fixing, without the requirement for surface apparatus.

The general conditions at each location will dictate the design stresses to be used in assessing the ultimate capacity of an individual anchor. Where laboratory tests are not available, full-scale insitu tests are required to establish the lower bounds of the substrate capacity.

A minimum fixed anchor length of three metres is recommended to account for local variables in substrate conditions.

In order to reduce the possibility of long term ground creep, factors of safety should be applied. These factors should be of the order of 3 to 4 dependent on soil consistency, life expectancy and their importance to the structure.

The fixed anchor length must be located beyond the critical zone, such as the wedge failure, slip circle, rock discontinuities in order to be effective. The free anchor length will depend upon the geometry of the location.

The anchors can act as a restraint, only accepting load if movement occurs, or they can be pre-stressed to a set load to provide an active force.

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The following pictures show the process of drilling for, installing and grouting the Cintec Ground Anchors.


Setting up the drilling rig


The drilling head


Adding mining barrel extensions


Mining barrel extensions


Drill head at full depth

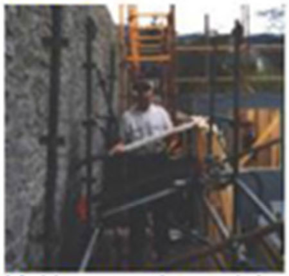

Inserting plastic tube liner to the drilled hole


Cintec anchor in its packing protects until needed


Removing anchor from the packing


Ready to insert anchor


Carefully placing the anchor


Making sure the sock is not bunched up at the end


Final few feet going in


Extracting the tube liner


Removing the tube liner


Grouting the anchor

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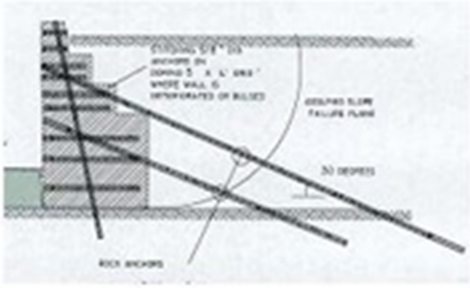
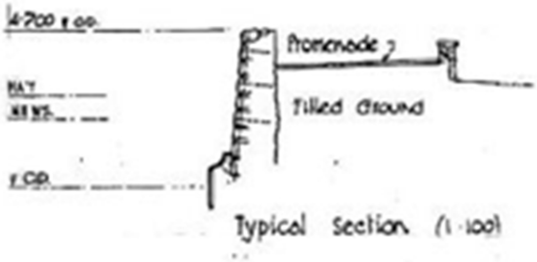
Click on the images to access the project information



New York Retaining Wall - Rotation & Delamination

Florida Sea Wall - Subsidence & Dislocation



Goodrington Sea Wall - Sliding & Delamination

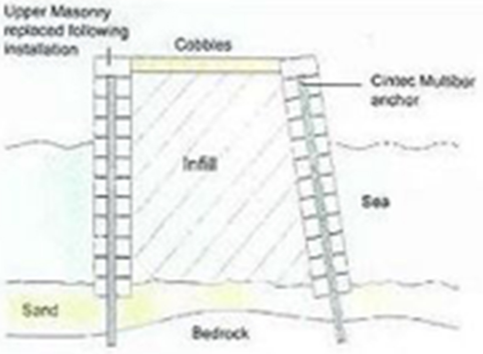
Blaise Castle Wall - Sliding

WANTAGE TOWN WALL, Berkshire

As found shored up ....Drilling and installing Cintec ground anchors

Mesh and face plates secured...........Final lime rendered finish applied

Malmesbury Town Wall - Deep Seated & Rotation



Hay's Dock, Lerwick - Subsidence & Sliding

CINTEC
REINFORCEMENT SYSTEMS

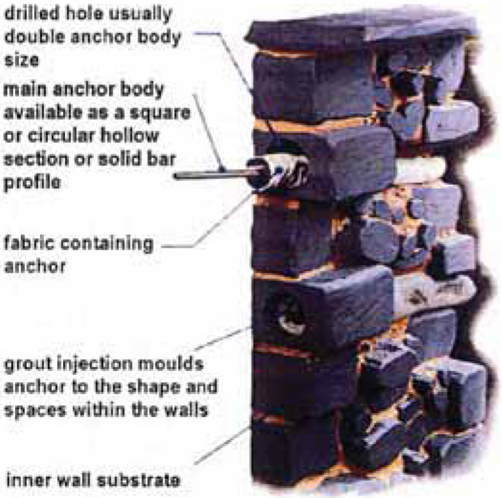
PARATEC

PARAPET WALL STRENGTHENING FROM CINTEC

No two masonry arch bridges are the same, and this also applies to their parapet walls. The requirements specified for individual walls can differ considerably and must reconcile a variety of needs. These may include impact containment, vehicle redirection, the protection of others in the vicinity, compatibility with the masonry structure as a whole, as well as the visual appearance of the strengthening solution implemented.

The Cintec Anchor System provides a highly versatile method of internal structural reinforcement that is tailored to meet the specific requirements of each parapet wall. This service, known as Paratec is backed by extensive research and development, this includes advanced computer modelling, practical testing and also the experience built up from numerous strengthening projects. The Paratec system can strengthen a masonry wall while remaining sensitive to the original architecture and without any narrowing of the road way.

The Anchor: The system comprises a steel bar enclosed in a mesh fabric sleeve, into this a highly specialised grout is injected under low pressure. This is a Portland cement based product, containing graded aggregates and other constituents which, when mixed with water, produce a pumpable cementitious grout that exhibits good strength without shrinkage. Installation is by precisely drilled holes using wet or dry diamond coring technology. The flexible sleeve of woven polyester restrains the grout flow and expands up to twice its original diameter moulding itself into the shapes and spaces within the walls. This provides a strong mechanical bond along the entire length of the anchor dispensing with the need for external anchor plates.



The size and type of steel anchor, the strength of grout and the diameter of the hole can all be varied to the required design parameters, these will include providing the appropriate stiffness compatible with the masonry.

Research & Development

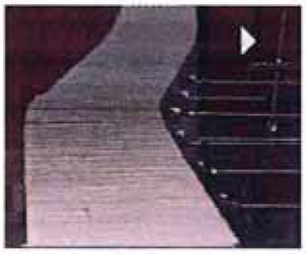
The comprehensive service offered by Paratec include advanced computer modelling techniques that simulate the effects of a vehicle impact upon a specified masonry wall. Working in conjunction with both software specialists and consulting engineers, Paratec utilises an advanced dynamic software incorporating a discrete element analysis technique that enables the behaviour of parapet walls to be accurately predicted under various circumstances.

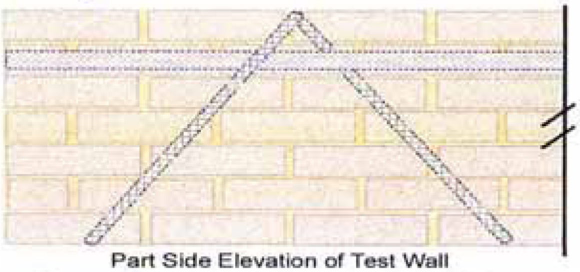
CINTEC
REINFORCEMENT SYSTEMS

Practical Testing: Tyne-Tees University

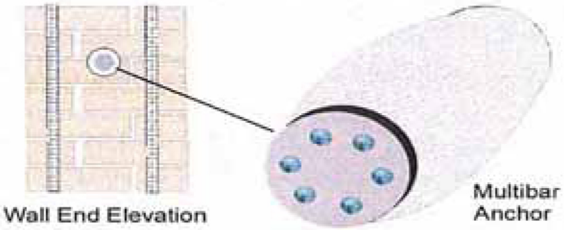
Dynamic full-scale parapet wall tests were undertaken in the heavy structures laboratory at Tyne-Tees University. The tests clearly demonstrate the robustness of parapet walls reinforced with Cintec masonry anchors. The walls were impact loaded using a falling weight test rig designed to generate the force/tme history of an actual vehicle impact test that had previously been recorded and analysed at MIRA.

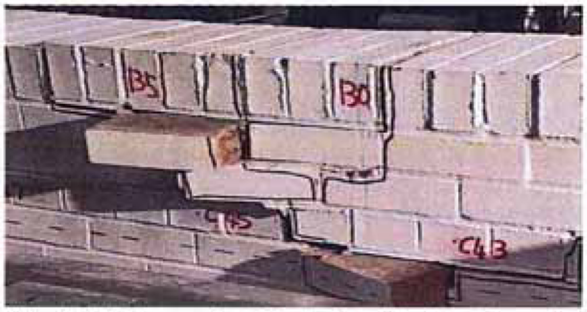
In this test, the Cintec reinforcement used was a 19.5 metre high yield MS multibar anchor comprising six individual stainless steel bars of 8mm in diameter. This was installed 370mm below the top of the wall. Raking anchors were also installed in pairs at 30° to the vertical. These were 1 metre long 3 strand 8mm diameter multibar anchors encapsulated in a 40mm diameter sock and installed in a 50mm diameter hole.





Part Side Elevation of Test Wall





Although the bridge was shunted by the force of the impact, it remained intact with no significant spalling. The picture above shows the wall face opposite to the point of impact after two consecutive tests.

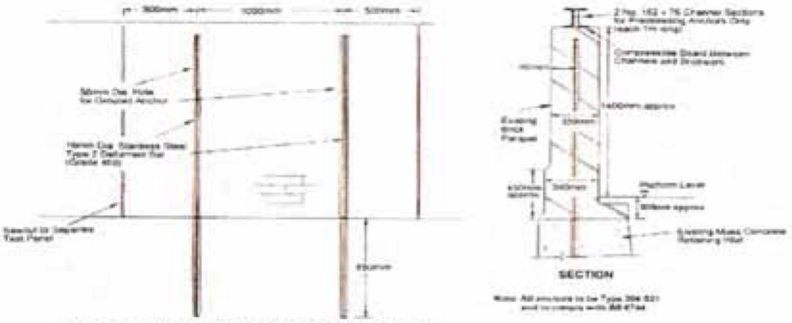
London Underground

London Underground has a great many brick walls and parapets supported on elevated structures. As it is the world's oldest underground system, many of the walls are between 100 and 150 years old and are consequently suffering from a degradation of the mortar which is invariably lime based.

An insitu load test was carried out in order to demonstrate the applicability of Cintec anchors for both stabilising these structures and for strengthening them against dynamic air pressure loading. The test was also used to confirm that the performance of the strengthened wall had been correctly calculated and thus provide assurance of the methodology.

Post-tensioning Cintec anchor in test panel.

Two 16mm diameter 2 stage anchors were installed vertically, the anchorage length within the supporting structure was then inflated and left to fully harden. The anchor was then tensioned and the second sock occupying the remaining space in the masonry wall was inflated.



Details of test panel strengthening scheme.

Once the anchors were cured, an applied wind loading was simulated by the application of a lateral point load on a horizontal spreader beam positioned at the walls centre. An incremental lateral load up to 3.5kN/m was applied by a hydraulic jack which demonstrated a linear elastic response.

The predicted response, calculated beforehand and based on assumed values for the material properties, was within 30% of the measured values. Bearing in mind the wide range of uncertainties in relation to the wall stiffness and strength, this demonstrated an adequately high level of accuracy. On completion of the test, no cracking or spalling was observed. It was concluded that the strengthening scheme presented both "an economic and aesthetic solution to the refurbishment of understrength and unstable masonry parapets".

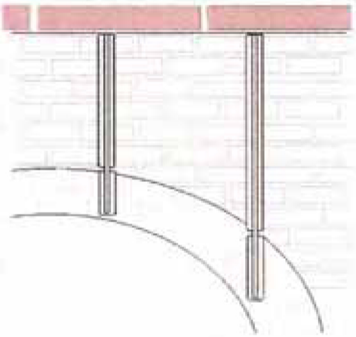

Testing In Progress. A hydraulic jack pushes against an anchored jacking frame.

CASE HISTORY - INCLINED PLANE BRIDGE, COALPORT

Spanning the river Severn at Coalport in Shropshire, the Inclined Plane bridge is a registered ancient monument and as such, any alteration to its appearance is unacceptable. The Archtec method of bridge reinforcement was chosen to increase the load bearing capacity of the structure, and a need was also recognised to strengthen its parapet walls.

A solution was achieved by the installation of Cintec 16mm studding anchors, of between 1.5 and 3 metres in length. These were designed with two individually inflated socks and were installed vertically at 1 metre intervals through the parapet walls and into the barrel of the arch. The lower (arch barrel) sock was then inflated and left to cure. The second sock was then inflated and placed under a tension of 10kN by using a tensioning plate. The grout was then cured and the tensioning plate removed.

Finally the sandstone parapet coping stones were replaced and two missing stones reproduced. The solution provided the necessary increase in wall strength without having any visible change to its appearance.



CASE HISTORY - WALCOT ROAD BRIDGE, TELFORD

Built in limestone and spanning the river Tern, Walcot Road bridge is an historic structure with a grade II listing. As it was constructed long before the development of motorised traffic, it is vulnerable to the modern demands placed upon it. The narrow roadway has led to numerous collisions and scrapes along its parapet walls for which Wrekin Council had correspondingly undertaken various stonework repairs. It was decided to pre-empt future repair work with a parapet reinforcement scheme. Cintec provided a solution that met both the engineering and aesthetic requirements. With the use of non-percussive diamond core drilling, thirty-six prestressed Cintec anchors of between 1.4m and 2.8m in length were installed vertically through the parapet walls and into the arch barrel. Core drilled sections of the monolithic coping stones were then replaced and grouted into the entrance of the anchor holes to provide an almost invisible finish.

Current research is focusing on the development of articulated anchor reinforcements. These are designed to fail progressively in order to absorb the energy of a vehicle impact while at the same time reducing the structural damage incurred by the bridge.

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