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 transferal 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 1n 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 219.1 KN/m2 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 tail.
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 CMI Engineering Dept
Mr Barnet of British Rail Intercity CMI Engineering Dept
Mr Dimmick of Cavity Lock Systems (now Cintec International).
Mr Parry of Cavity Lock Systems (now Cintec International).
Mr Woodhouse of Fordharn: Johns Partnership.

The anchors were installed in the period February - May 1992 and tested between June 1992 and December1992.

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: $\text{Area required} = \frac{\text{Load}}{\text{Fy}}$

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 = **INSERT SCANNED FORMULA HERE**

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:-

where fbu = the design ultimate anchorage bond stress.

B = coefficient dependent on type (0.5 x 1.4 = 0.7)

= 4.43 N/mm^2 cu = 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:- Tf = **??** D L S

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

0= 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

$$Tf = \frac{pD\ L\ Tult}{\text{Factor of Safety}}$$

Where Tuft = 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.

$$Tf = \frac{pD\ L\ S}{\text{Factor of Safety}}$$

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

$$Tf = \frac{pD\ L\ aCu}{\text{Factor of Safety}}$$

Where a··adhesion factor 0.3 - 0.45 verified by testing.
Cu = average undrained shear strength of substrate.

The value 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:-

$$Ts = \frac{pD\ L\ B}{\text{Factor of Safety}}$$

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 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.

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

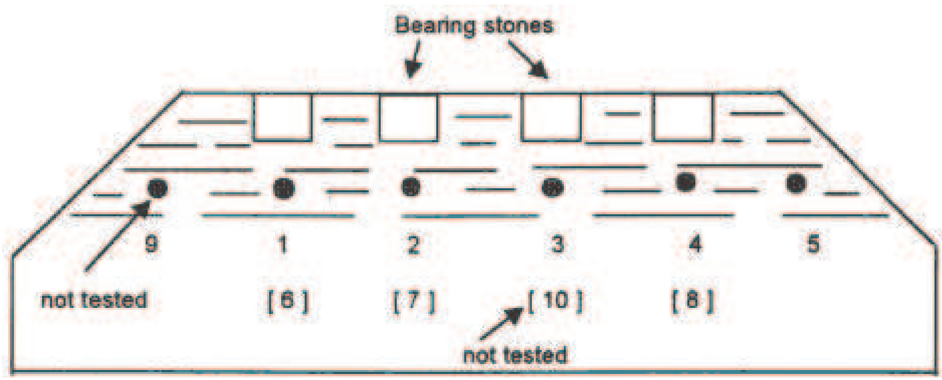
The testing of the ground anchors showed that the Cintec System could be successfully used in even the most difficult of ground conditions and achieve results in excess of expectations.

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 APRIL1993

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

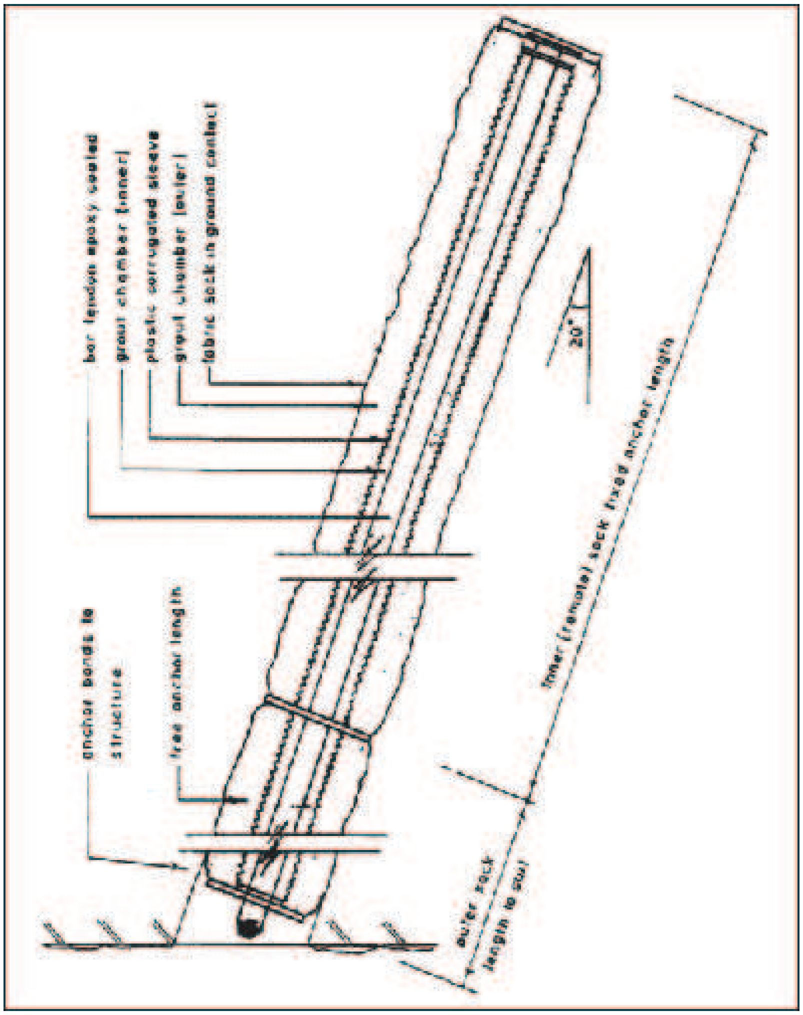
ANCHOR NUMBER	ANGLE OF INCUNATION	TOTAL LENGTH (M)	FIXED ANCHOR LENGTH OR LENGTH OF EMBEDMENT (M)	HOLE DIAMETER (MM)	TEST LOAD [T]
1	20°	5.45	4.1	124	15
2	20°	3.95	2.6	124	18
3	20°	3.45	2.1	124	18
4	20°	3.95	2.6	124	19
5	30°	5.45	4.1	124	13
6	20°	4.45	3.1	124	18
7	20°	4.45	3.1	124	17
8	20°	4.95	3.6	124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

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

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/mm^2)	Shear stress soil anchor interface (KN/m^2
1	20°	5.45	4.1	124	$1.599x10^6$	15	150	0.0938	93.8
2	20°	3.95	2.6	124	$1.014x10^6$	18	180	0.1775	177.5
3	20°	3.45	2.1	124	$0.819x10^6$	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	$1.599x10^6$	13	130	0.0813	81.3
6	20°	4.45	3.1	124	$1.209x10^6$	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	$1,404x10^6$	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

GROUND ANCHOR DETAIL TO ABUTMENTS



Drawing Title: