Cintec's
award winning

ARCHTEC

strengthening,
repair and stabilization
of masonry arch bridges

CINTEC
NORTH AMERICA
SECURING THE PAST FOR THE FUTURE

the Cintec System

the cintec commitment

Cintec world wide recognizes and respects the feelings of local communities in respect to what they regard as Heritage or Historic buildings and structures, regardless of whether or not the buildings/structures are formally designated as such. To this end Cintec works to the guidelines, the principles of the Venice Charter of 1964 and the Burra Charter of 1979.

bridge requirement

In North America there are over 1,000 masonry arch bridges. Europe has many thousands of such structures: 40.000 in the UK alone are in continual use by highways, railways, and waterways. Most are well over 100 years old, and as of January 1999 the European directive 96/58/EEC requires that all major (trunk) road bridges be capable of 40 Tonne (89,500 lbs) axle loading.

how it works

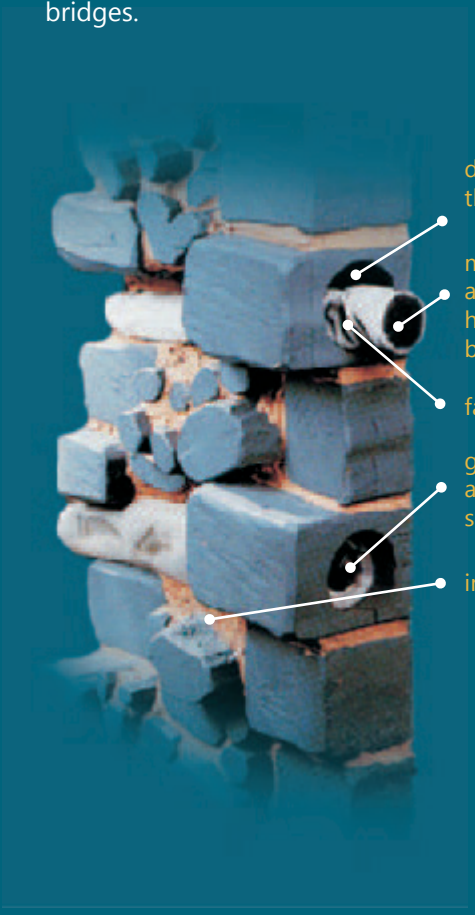
The Cintec Anchor System comprises a structural member in a mesh fabric sleeve into which a specially developed grout is injected under low pressure.

Installation is through precisely drilled holes produced by wet or dry diamond coring technology. The flexible sleeve of woven polyester restrains the grout flow and expands up to twice its previous diameter, moulding itself into the shapes and spaces within the walls to provide a strong mechanical bond along the entire length of the anchor. This will often dispense with the need for patress plates on the exterior of the structure.

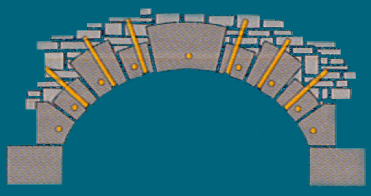
The grout is a Portland cement based product, containing graded aggregates and other constituents which, when mixed with water, produce a pumpable cementitious grout that exhibits good strength without shrinkage.

archtec response

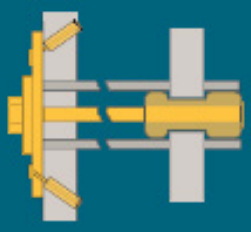
Archtec provides a unique bridge reinforcement system - a complete diagnostic, design and installation service, utilising state of the art technology and drilling methods specially designed to strengthen masonry arch bridges.



applications



arches and bridges



structural reinforcement

hanging walls

viaduct foundation

retaining walls

proven performance

The intrinsic qualities of the Cintec Anchor are well documented through years of extensive testing. With each project and application, from high-rise buildings, to ancient masonry structures, to bridges and retaining walls, Cintec ensures that the physics behind the methodology are proven to be effective.

Cintec Anchors withstand forty year aging cycle simulations

extreme temperature testing shows the Cintec Anchor withstanding temperatures of 212 degrees F (160oc) for two hours

performance

An independent study carried out by Building Research Establishment involved accelerated age testing. This simulated a forty ye aging cycle and confirmed the anchors' long term performance.

Freeze-thaw testing of Cintec Anchors showed no appreciable deterioration after 100 cycles

Cintec anchors are dramatically more environmentally friendly than conventional methods

durability

freeze-thaw

Following rigorous testing in North America by ArconTEST Incorporated, the report on the Uni-directional Freeze-thaw Performance of Cintec Masonry Anchors (to EN 772) found no appreciable loss of grout or encasing brickwork after a full 100-cycle test.

fire

Fire testing at the Building Research Establishment (U.K.) in 1993 confirm that the Cintec Anchor System, when installed correctly, have a fire period requirement of up to 2 hours, at 160°c (212°F).

TRL test: from 22.5 Tons (20 tonnes) to 46 Tons (41 tonnes)

environmental

In many ways, the Archtec system is a wise environmental choice:

- it typically consumes 90% less energy than conventional methods
- it has virtually no impact on the environment and sensitive waterways
- it does not deface the appearance of structures and bridges
- Archtec construction areas have a small ''footprint''

load vs. displacement test of arch model shows a dramatic increase in strength

strength and flexibility

Laboratory models of an arch bridge were constructed in brick, based on an original bridge in the UK. The load point failure point of one model was 22.5 Tons (20 tonnes). Following strengthening by single-rebar anchors, their precise location being determined by state-of-the-art design, the load failure point was raise to 46 Tons (41 tonnes.) Strengthening using newer, multi-bar anchors raised the load failure point to 50.4 Tons (45 tonnes). Overall the following results were demonstrated:

- load-bearing capacity of the arch is increased by a factor of 2.05
- the first crack or hinge does not occur under the load-line
- overall, the installed anchors delay the formation of hinges
- the bond between anchors and masonry is sound
- the strengthening is relatively easy to install
- the system demonstrates significant flexibility and increased ductility

award-winning technology

Cintec has been honoured with a number of coveted awards for its engineering and design.

ENVIRONMENT AWARD FOR ENGINEERS

THE HISTORIC BRIDGE AWARDS, 2001
The Winston Bridge Strengthening Project, U.K.

THE INSTITUTION OF ENGINEERS, AUSTRALIA
Engineering Excellence Award 2001, Australia

THE HISTORIC BRIDGE AWARDS, 2001
The Coalport Inclined Plane Bridge Strengthening Project, U.K.

case histories
road bridges

Newcomers Mill Bridge
Maryland, USA

The structure

Newcomers Mill Bridge (route MD 733A) on the old National Highway is close to Frostberg, Garrett County in Maryland. The Bridge is one of seven remaining stone masonry bridges in the county constructed between 1813 and 1850. It is a single span masonry arch bridge over the Savage River and has significant historic value. The arch barrel is constructed from random rubble with squared voussoirs. Spandrell walls and parapets are built from roughly squared rubble.

The problem

At the time of Cintec's inspection (Nov 1999) the southern spandrel wall was in a serious state of disrepair and in imminent state of collapse.

The solution

A submission was made to Maryland State Highway Department and after the installation of over 45 Cintec Anchors, some measuring up to 28 feet (8.53m) in length, masonry repairs and low pressure grouting, this Historic bridge is once again safe.

Snowbridge
Glasgow, Scotland, U.K.

The structure

Hidden in the tranquil gardens of Kelvin Grove Park, Glasgow, Scotland, the Snowbridge was thought by many to have gracefully retired into obscurity. Its past glory of being the main means of disposing of the accumulated snow from the entire main thoroughfares of Glasgow had been superseded decades before by mechanical loaders.

The problem

With its retirement, it suffered, like most obsolete structures, with neglect and lack of maintenance due to the low priority it rated in budgets.

In 1987, CINTEC was asked to provide an estimate to rectify the many years of neglect. Following a complete survey and report from the Engineers Ove Arup and Partners, a comprehensive maintenance and anchoring scheme was presented to the City Council to bring the structure to a safe condition.

The solution

The scheme principally provided for the introduction of square hollow structural stainless steel anchors to the voussoirs and intrados of the arches and spandrel walls. The drilling chosen was wet diamond drilling with core retention to the natural stone structure. This provided that desired drilling accuracy and the need to reduce the vibration to a minimum in the fragile structure.

The proposals were kept in abeyance for several years before work commenced. Indeed, serious consideration was given to demolish the whole structure until it was found to contain optical telecommunications between the USA and the UK.

Bodiam Bridge

Hertfordshire, U.K.

The structure

The site is that of a Roman road, constructed on a twigs and rubble causeway to serve an ironworks. Built in 1797, the bridge is a single track, hump-backed triple arch structure in brickwork and there are signs of various remedial works throughout its life.

The problem

There appear to have been problems with the original construction. There is pronounced twist in the lower courses of brickwork towards the northern end of the bridge, which disappears as the construction continues upward. In recent years, the bridge has suffered from the effects of increasingly heavy traffic exacerbated by the very cold winters of 1986 and 1987. This has led to the cracking of brickwork adjacent to the arch voussoirs, some movement in the spandrel walls and delamination of the wing walls at the south end. The County Council approached Cintec for a proposal to use grout injected anchors to tie across the arch.

The solution

To prevent any further spreading of the arches, it was proposed to tie across the full width of the bridge, staggered from both sides. This ensured that the lateral stresses were not transferred to a single plane nearer the centreline of the bridge causing new cracking at this point. Following grouting of the anchors the holes were made good with coloured mortar to match the brickwork.

Smaller anchors were also used for repair of the southern wing walls where core drilling of bulged portions of the wall showed that a half brick facing skin was delaminating from the full thickness of the wall. High bond capacity allowed an effective anchorage into a single half-brick skin, achieved while still having the end of the anchor recessed into the face.

Broxbourne Arches

Hertfordshire, U.K.

The structure

The strengthening of Broxbourne Arches was carried out in January 2000. It involved work on 14 separate arches. All work had to be completed from underneath in order to avoid interfering with the road traffic on the arches. After the strengthening work, another company worked on the bridge surface to relay pipelines and upgrade the surface.

The problem

The strengthening method was designed by Gifford and Partners. Their assessment was that the crack pattern observed in the arches was not indicative of live load effects and indicated a progressive type of failure. A live load assessment had shown that the structure had sufficient capacity to carry the required live loading of 45 Tons (40 Tonnes) gross vehicle weight, and that the foundations also showed no signs of distress. Records indicated that the arches had, at some stage, been back-filled with mass concrete. While providing the arches with a substantial increase in live load capacity, the issue of thermal expansion had been overlooked. Analysis was carried out to understand the behaviour of the structure under thermal loading, and this confirmed the crack pattern observed on-site. Thermal expansion of the concrete had taken place pushing the arches laterally and producing a domino-like effect. Cracks had appeared where hinges had developed as a result of the lateral forces. Design work was then carried out to stabilize the damaged structure and provide additional capacity across the hinge positions.

The solution

The project involved the excavation of some of the ground in the immediate area of drilling to provide the angle for the insertion of the main anchors. A total of 75 Stainless Steel strengthening anchors were installed, as well as 12 transverse anchors. The project was completed in 5 weeks — the contracted period.

Red Bridge

Campbell Town, Tasmania, Australia

The structure

The "Red Bridge" across the Elizabeth River at Campbell Town in Tasmania is the oldest surviving brick arch bridge in Australia. It consists of three segmental arch spans of 25 feet (7.6 metres) and was built by convict labour between 1836 and 1838 using red clay bricks made on site. It rests on a basalt stone substructure and uses sandstone for the piers, abutments and cappings.

The problem

The bridge was originally built wide enough to take two modern traffic lanes, plus footways. There is presently no convenient alternative route, nor is one planned in the near future. The Tasmanian Department of Infrastructure, Energy and Resources, ordered a restoration to structural integrity and strengthening to take modern heavy vehicles. Part of the "wish list" also required strengthening to the new SM1600 loading which allows for future increases and has loads in excess of 40 Tons (36 tonnes) on a 3-axle group.

The solution

A consortium was formed by the Cintec Australian arm with Van Ek Contracting of Tasmania who are known for their expertise in conservation of old bridges and the building of new ones. When expressions of interest were called from all over Australia for a design and construct contract, only the Cintec consortium using the Archtec process was able to satisfy the Department and a contract was negotiated without further tendering.

Analysis by the Archtec consultants, Gifford and Partners of England, has shown that the bridge could be strengthened to the required SM1600 loading. Specially formulated lime grouts and mortars were used to ensure that the bridge meets the specification requirement for the forseable future without major repairs.

Aldie Bridge

Aldie, Virginia, USA

The structure

This historic 180-year-old stone arch bridge which carries Route 50 over the Little River in Aldie, Virginia, was found to require sensitive masonry restoration and structural strengthening after a statewide bridge survey.

Built originally for horse and buggy traffic, Aldie Bridge carries thousands of vehicles each day. The bridge is 23 Feet (7m) wide and with two single lanes and there are no sidewalks or curbs. The stone arches have spans of approximately 31 feet (9.45m) and a rise and fall of about 5 feet (1.52m).

The problem

The Virginia Department of Transportation (VDOT) concluded that the increased traffic volume and vehicle weights from local development along Route 50 caused the bridge to show many signs of being overloaded, which accelerated the normal failure mechanisms of the structure.

One wing and spandrel wall bowed out dangerously and a support buttress was showing signs of accelerated weathering due to mortar joint deterioration throughout the bridge.

The solution

Utilizing finite element computer modeling and simulation software, Cintec America calculated all of the stress factors placed on the bridge with and without the addition of customized Cintec Structural Anchors. After analysis of these results, placement of Archtec Reinforcement Anchors were designed so that the bridge would conform to federal AASHTO standards.

Safety and environmental protection measures were fully and successfully deployed throughout the project.

It was important to the community and VDOT to keep the bridge open to traffic at all times since the local fire department was located at one end of the bridge. In order to cope with the high volume of rush hour traffic in and out of Washington DC, it was necessary to switch to nighttime work when the centerline anchors were installed.

On completion, the Archtec System was praised as being an innovative means of strengthening the Aldie Bridge to meet future traffic loads while maintaining its historic character.

Puente Laguna Condado

San Juan, Puerto Rico

The structure

The Puente Laguna Condado is one of the principal entrances to San Juan Puerto Rico. It is a multiple span steel girder bridge built in 1926.

The problem

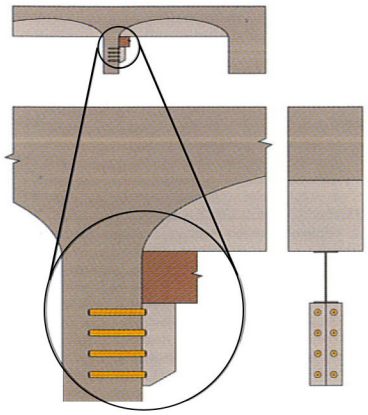
It was determined in 1997 that deterioration of the bridge structure due to exposure to the marine environment had weakened the bridge to the point where it was declared unsafe for the rated load. It was not possible to de-rate the loading due to the heavy traffic volume at this location.

The solution

As an emergency measure, steel seat brackets were installed under each beam. These seat brackets were connected to the historic concrete piers with Cintec Anchors.

Cintec Anchors were selected for several reasons.

- the condition of the concrete in the piers was not good and the oversized bearing of the grout in the Cintec sock provided a superior bearing area on the concrete.
- The oversized holes allowed for adjustments in the alignment of the anchors if obstacles such as rebar were encountered during drilling of the holes.
- the Cintec grout material is compatible with the original cementitious material in the piers.
- The Cintec Anchor system is very resistant to corrosion and fire.
- the Cintec Anchors can be installed in wet environments (even underwater) and where the substrate is salt laden.



Clifton Bridge

Scottish Borders, U.K.

Built of random whinstone, these two spans of over 22 feet, 6 inches (7m) were assessed as having a carrying capacity of 8.4 Tons (7.5 tonnes). The bridge is located in a rural environment with no alternative route for some users. Therefore ARCHTEC was chosen in order to cause minimal disruption to traffic and for its environmental advantages. A "saddle system" would have been very disruptive. The Scottish Borders Council was restricted to a two week window of opportunity in order to suit the local farming community. The bridge was completed on time and to budget and organised so that it remained open to traffic throughout the process of installation.

Peters Bridge

Ballymena, Ireland

Bridging a busy single-track railway line, a rating of 11.20 Tons (10 Tonnes) was assessed for this single 28 feet (8.6m) span masonry structure. Strengthening to a rating of 44.8 Tons (40 Tonnes) was required. Twenty-six 10 feet (3m) reinforcement anchors were installed to achieve this new load capacity. The holes are made with non-percussive diamond drills causing very little vibration, however, in order to minimize the risk of debris falling onto the track, 'fortrac' safety netting was fixed to the underside of the bridge during the installation process.

Pont Llanafan

Ceredigion, Wales

This historic structure became the first Archtec project in Wales and required the listed building consent of the heritage authority. The bridge remained open throughout with the central holes being drilled at night. Twelve anchors, averaging 23 feet (7m) in length were used for strengthening and three longitudinal anchors for barrel stabilization.

case histories
rail bridges

Outwood Viaduct

Radcliffe, U.K.

The Structure

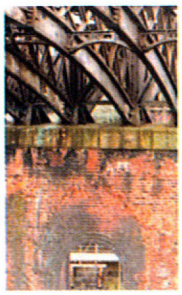
Following its closure in 1966, Outwood Viaduct had fallen into dereliction. However, its proposed demolition by British Rail was forestalled due to public objection led by the Railway Heritage Trust and it was eventually given Grade II listed status. It spans the river Irwell at the western edge of Radcliffe, Greater Manchester. The spans were fabricated and erected in 1881 and have an overall length of 336 Feet (102.4 m). Each span comprises six cast iron open spandrel arch ribs with lateral bracing.

The problem

British Rail had previously attempted to strengthen the four tapering brickwork pillars by adding new masonry to the original single archway piercings located in each pier. However, this new work had begun to detach from the original structure. Extensive cracking was visible between the old and the new.

The solution

Cintec supplied 108 threaded bar and rebar stitching anchors ranging from 2.5 feet (.75 m) to 30 feet (9 m) in length. These were installed through the cracks to re-connect the inner reinforcement brickwork to the original structure as indicated in the design proposal below. After renovation, Outwood Viaduct was formally opened as a footpath, bridleway and cycleway in 1999 by Sir William McAlpine, President of the Railway Heritage Trust.



Teviot Viaduct

Scottish Borders, U.K.

The structure

Built in 1847, the Teviot Viaduct spans the River Teviot at Roxburgh in the Scottish Borders.

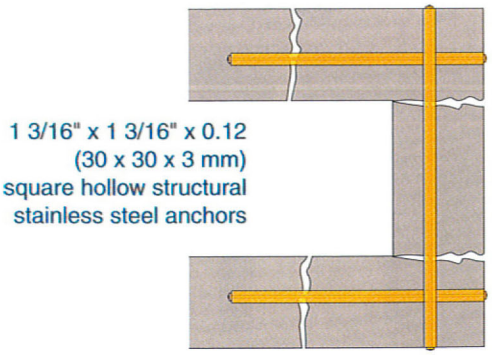
The problem

As a consequence of no longer being part of the rail system, the stone masonry structure had fallen into disrepair with extensive cracking to both the arches and the piers. A number of stone blocks had also come loose and were missing. However, because of its significance to local heritage, the viaduct was considered worthy of preservation. Funding was made available by the British Railways Board and the Railway Heritage Trust.

The solution

The first phase of restoration involved the replacement of broken and missing voissoir stones from the arch barrels. In order to reduce the risk of a progressive collapse, neighbouring stones were held in position by square hollow structural stainless steel stitching anchors 4 Feet (1.22 m) in length. This consolidated the arch while the replacement stones were installed.

The second phase of work involved interlocking the outer masonry walls of each pier. In total, 112 anchors were installed.



Worcester Viaduct

Worcester, England, U.K.

The structure

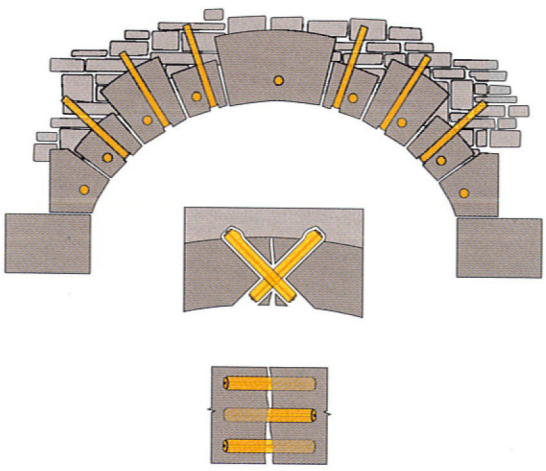
Worcester Viaduct comprises of sixty-five brickwork arches rising from approximately a two-storey height near the railway station, to over a three-storey height as it approaches the river.

The problem

Lack of of proper drainage within the arch had led to the spandrel walls being forced away from the intrados arch with longitudinal cracks close to the longitudinal edges of the bridge. Water penetration had also contributed to cracking at the springing of some spans and delamination of external parts of some columns. These problems had been exacerbated by weathering, particularly freezing and thawing. Previous attempts to restore the structural integrity were evident, but had proved ineffective.

The solution

Transverse Cintec Stainless Steel Structural Anchors were installed to restore the integrity of the spandrel wall/intrados arch connection. Stitching anchors were then angled across longitudinal cracks to restore structural integrity and the cracks were then filled. Transverse and diagonal stitching anchors were installed to restore the strength of the delaminated columns and the cracks filled. Drainage holes were drilled through the intrados and plastic pipes installed to relieve the existing water pressure. To date, five spans have been renovated using the Cintec System and further spans will be renovated as part of an ongoing maintenance programme.



Royal Border Bridge

England, U.K.

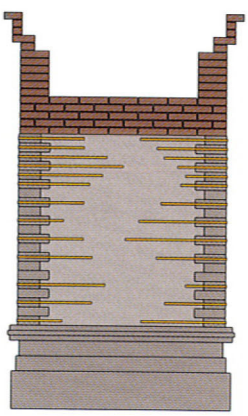
The structure

As part of Railtrack's major programme of repair and refurbishment of the land-based arches, work was authorised on numbers 1-15 of the Royal Border Railway Bridge. The bridge carries the main Inter-City East Coast Rail Line between Edinburgh (Waverley Street) and London (King's Cross). George Stephenson's magnificent 28-arch, 128 feet (39m) high viaduct spans the tidal estuary of the River Tweed between Berwick and Tweedmouth, two and a half miles south of the Anglo-Scottish border. Queen Victoria and Prince Albert opened the 2160 feet (658m) long bridge in 1850; the structure celebrated its 150th anniversary at the turn of the century. The project was complicated by both environmental and technical factors.

The problem

Green nylon based Debri-Mesh surrounded the main work areas to contain dust and debris from the drilling which, if uncontained, would cause environmental problems to the residents of the 36-house Riverdene Estate lying directly below the bridge. The covering material also provided a degree of shelter from the strong prevailing winds which blow eastwards down the Tweed River Valley.

Furthermore, certain areas of the 60 feet (18.29m) span brick arches provided roosting areas for galleries of bats. Because they are a "protected species", provision had to be made to preserve the bats' areas. The ornamental stone-work which forms the top parapet of the viaduct, is also a nesting site for House Martins; also in 1996 a pair of Kestrels were observed nesting under one of the electric catenary poles.



The solution

Cintec supplied 1256 anchors spread over 15 arches and were installed horizontally through the voussoirs to varying sizes and depth, thus avoiding creating a shear line in the parent material.

Killiecrankie Viaduct

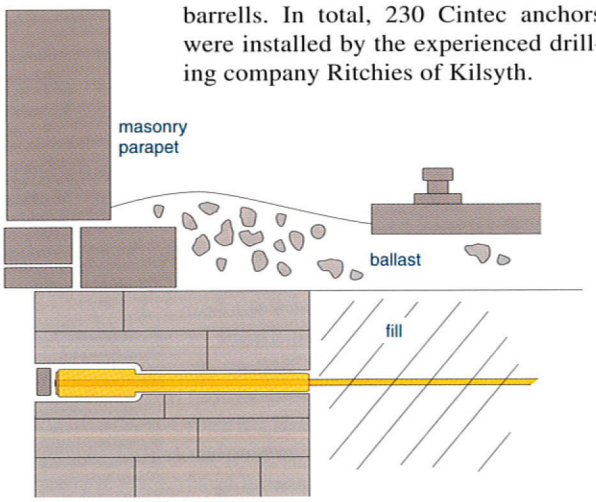
Tayside, Scotland

The structure

Killiecrankie Viaduct was both repaired and strengthened. The work was intended to increase maximum track speed and accommodate intercity trains travelling up to 125 mph (201km/h). These improvements were part of an extensive program covering the entire length of the Highlands Railway from Perth to Inverness in Scotland. Following the contours of Glen Garry, the curvature of the multi-arch structure added to the engineering challenge. Engineering consultant Scott Wilson Glasgow, assessed that strengthening would be required in order that the viaduct withstand the increased lateral forces being exerted by high speed trains.

The solution

Deformed rebar anchors in lengths between 3 feet (1m) and 15 feet (4.5m) were installed horizontally under the full width of the viaduct The anchors passed from the masonry spandrel wall through the springing vee joints to the opposite spandrel wall. Only the anchor sections located within the spandrel walls were sleeved and inflated with grout (see below). To increase tension values, the anchors were installed in stepped bore holes, allowing the sleeve to expand beyond the diameter of the inner-bore hole. Other anchors were installed through the voussoir stones into the masonry arch barrells. In total, 230 Cintec anchors were installed by the experienced drilling company Ritchies of Kilsyth.



Deansgate Viaduct

Manchester, England

The structure

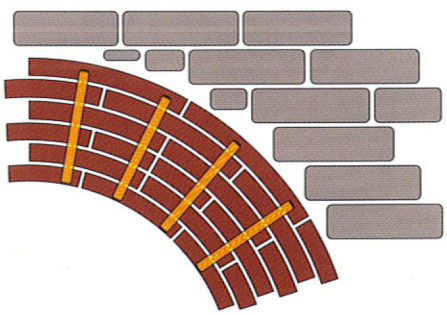
The busy Deansgate rail viaduct is situated in the heart of Manchester, spanning numerous buildings, roads and canals.

The problem

In 1997, the normal daily flow of railtraffic was disrupted by a destructive fire which took hold in a workshop located directly underneath. The subsequent heat generated by the blaze caused extensive damage and a weakening of the seven rings of masonry that form the arch barrels. The surface ring of brickwork completely delaminated and collapsed to the ground below.

The solution

A team of consulting engineers assessed the damage, and recommended a Cintec Reinforcement solution. Any remnants of the outer ring were completely removed and the remaining six rings were hammer tested to locate the extent and area of internal delamination. Two arches were found to be in need of repair. In total, approximately 500, 24 inch (609mm) long Cintec Type RAC Stainless Steel Anchors were installed, perpendicular to the arch and at spacings of 20 inches (508mm). The anchors were staggered to avoid the formation of sheer lines. Because of the overhead installation configuration, each anchor was fitted with an air-vent tube to ensure full grout inflation without risk of air pockets being formed at their remote end. All anchors went no further than half way through the sixth ring so as not to puncture the original waterproof membrane that protects the arch barrel from the arch infill. Finally, the original appearance of the arches was restored by grouting an original piece from the drilled cores back into the mouth of each anchor hole. The completed work was rendered invisible to the naked eye and the viaduct was once again in operation, servicing Deansgate Station and the G-Mex Conference Centre.



applications

Traditional methods of structure and foundation repair are time-consuming, very expensive, and often just not feasible. By comparison, the extraordinarily versatile Cintec anchor system can address fundamental structural problems with relative ease.

ground anchors

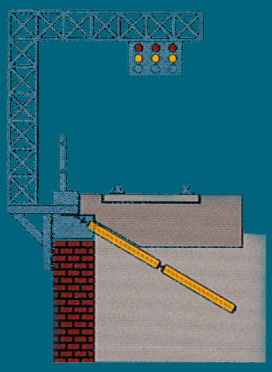
This system is used to tie bridge abutments back to embankments of poor ground conditions.

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

load vs. displacement test of arch model shows a dramatic increase in strength

cantilever signal systems

The Cintec system was required to secure the cantilevered signal tower to the bridge arch. The Cintec system used would require only minimal disruptions instead of the proposed six weeks.



a simple and elegant solution makes for a relatively quick and inexpensive reinforcement
- Fenchurch Street Station, London, U.K.

tunnels

The Archtec system offers considerable benefits in strengthening masonry tunnel arches. Where conventional methods require large scale upgrading and modification to the original structure, Archtec strengthens using the original structural elements of the tunnel.

The method used is based on access and cost factors specific to each site, and can be varied along the length of the tunnel, depending on access considerations. The reinforcement can be installed either from the interior of the tunnel or from the top side.

Archtec allows the tunnel to continue in limited use, avoiding the cost of detours or alternate means of transport

the Archtec System can address a variety of problems presented by tunnel reinforcement

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.

parapet walls can be strengthened at a fraction of the cost of traditional methods

Cintec on the Web

Visit our website for up-to-date information and test data together with information on the various projects carried out worldwide.

www.cintec.com

United States

Cintec America Inc.
200 International Circle, Suite 5100,
Hunt Valley, Maryland
21030, USA
Tel: 1 410 761-0765
1 800 363-6066
Fax: 1 800 461-1862
E-mail: solutions@cintec.com

Canada

Cintec Reinforcement Systems
38 Auriga Drive, Suite 200
Nepean, Ontario, Canada
K2E 8A5
Tel: (1) 613 225-3381
Fax: (1) 613 224-9042
E-mail: solutions@cintec.com

United Kingdom

Cintec International Ltd.
Cintec House
11 Gold Tops
South Wales, UK
Newport NP204PH
Tel: +44 (0) 1633 246614
Fax: +44 (0) 1633 246110
E-mail: hqcintec@cintec.co.uk