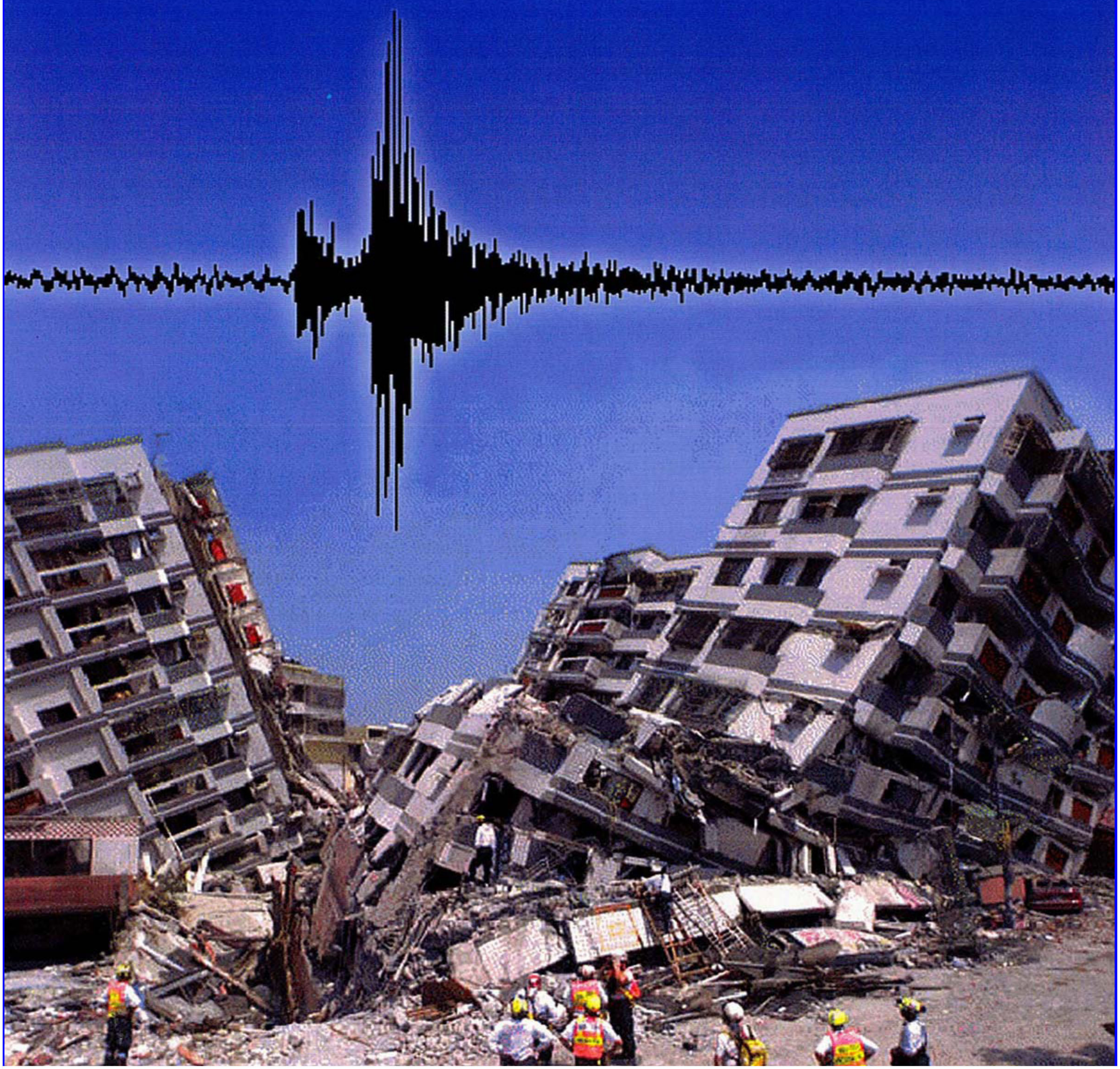
SEISTEC

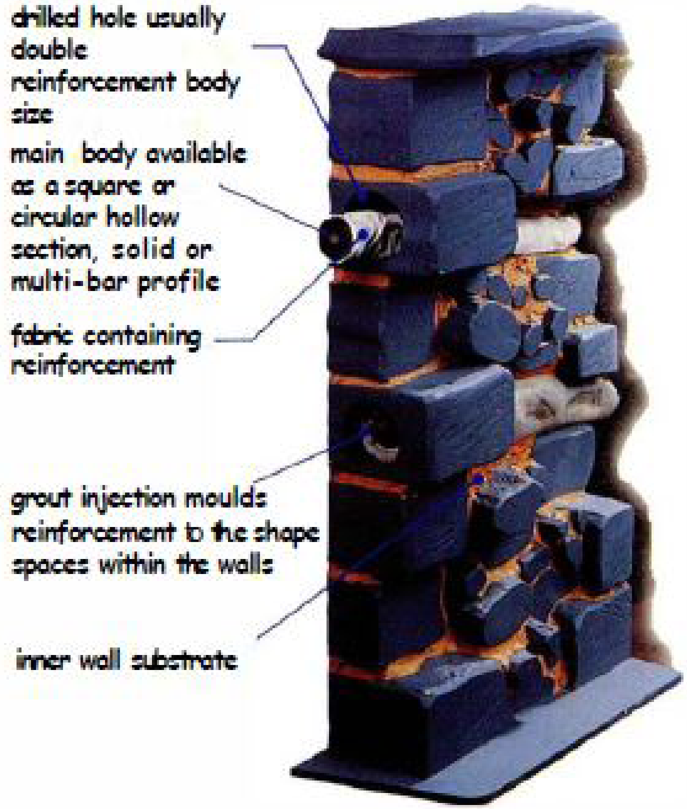
SEISMIC REINFORCEMENT SYSTEMS FROM CINTEC



Cintec's Reinforcement System

The Cintec Reinforcement System is acknowledged by civil engineers throughout the world to be a highly effective and versatile method of structural reinforcement. Its unique design features allow for adaptations that meet the specific strengthening and repair requirements individual to each project. In recent years, extensive research and develop-ment have focused upon the contribution Cintec Reinforcement can and do provide in the fields of seismic **upgrading** and repair while still remaining sensitive to the original architecture.

The principles of the Cintec System.



The Cintec reinforcement system comprises a steel bar enclosed in a mesh fabric sleeve into which a specially developed grout is injected under low pressure. 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. Installation is by precisely drilled holes using wet or dry diamond drilling 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. This provides a strong mechanical bond along the entire length of the reinforcement without the need for unsightly external tile plates on the exterior of the structure. in brief Cintec Reinforcement has the following advantages:

- **Custom designed for each project**
- **Cementitious, Inorganic grout and therefore sym-pathetic to original structure**
- **Age tested for durability**
- **Invisible when installed**
- **Resistant to fire**
- **Controlled grout flow and containment**
- **Quickly installed**
- **Approved by heritage organizations world-wide**

The size and type of steel, the strength of grout and the diameter of the hole can all be varied to provide the required design parameters and to provide an appro-priate stiffness compatibility with the masonry. The bond strength between the grout and the masonry are usually derived from static pull out tests.

Non Percussive diamond drilling removes core into which a reinforcement will be installed.

Both on-site and laboratory testing provide shear and tensile loading capabilities. Booklets of data are available.

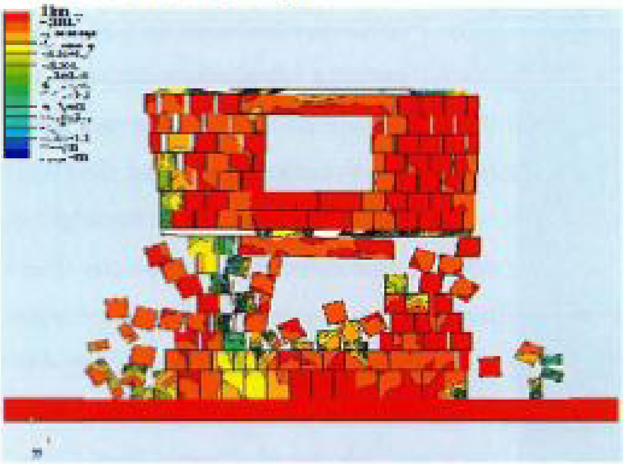
Seismic Research & Development

In order to provide the comprehensive service Cintec has to offer, advanced computer modelling techniques have been developed which simulate masonry structures both with and without strengthening.

The Software

Simulating discontinuous structures such as masonry through the use of continuum based numerical models was not considered sufficient to provide the required level of accuracy and generally did not provide a practical method of analysis for masonry. Such techniques fail to accurately predict the dynamic mechanisms involved when initially isolated parts react together. Because of these inherent drawbacks Cintec employs a discrete element technique.

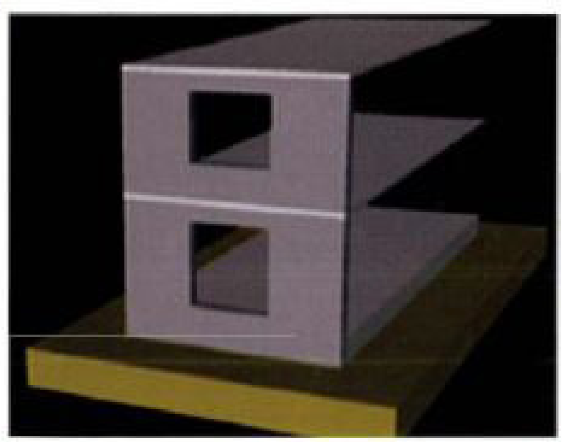
The discrete element software in action.



A modelled unreinforced structure during seismic loading. Various combinations of reinforcement patterns are tested to establish their performance under loads and their optimum locations.

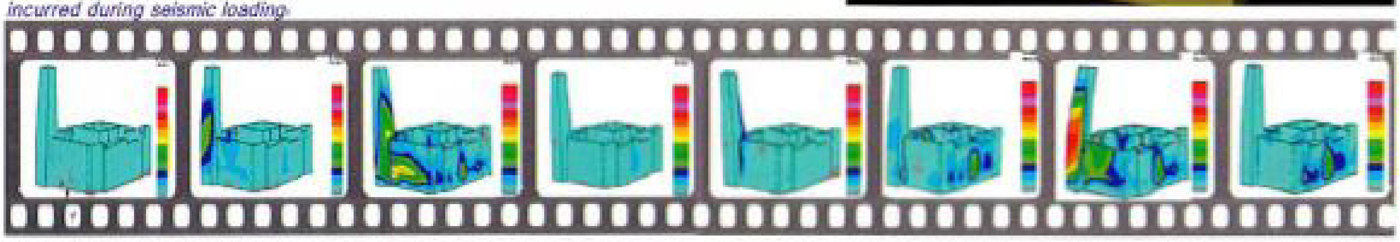
Working closely with consulting engineers, Cintec utilises an adaptation of this advanced dynamic software which has been adapted to represent differing masonry properties. These range from **Macro blocks** with essentially no strength at the joints - (commonly found in historical structures), **Brittle Material;** (where blocks and joints have predominantly similar strengths as is often the case for modern forms of construction) and **Brittle Macro Blocks** which uses the macro block approach but with brittle materials that permit block representation to fracture into further parts.

Cintec reinforcement systems are represented explicitly in the modeled masonry. They are designed not to be deliberately stressed, but to attract load during a seismic event. The modeled reinforcement permit recovery of bond stresses, axial stresses and slippage along the length of the reinforcement at any time during loading. Various strengthening arrangements are simulated to achieve the optimum strength and ductility for an individual building. These can be in horizontal, vertical and diagonal arrangements as well as in combined patterns. Backed by this research, Cintec can offer a rapid evaluation of structures and provide the level of strengthening most appropriate for each building.



A typical model arrangement for an idealised building. >

Computer animations using the discrete element technique visualise potential stresses incurred during seismic loading.



Practical Seismic Testing

Verification for simulated computer modeling derives from a series of actual tests carried out in both the field and the laboratory.

In a joint venture employing Cintec Reinforcement for strengthening

masonry arch bridges, the discrete element technique is used to calculate their collapse loads. The results correlate very closely with the practical test to destruction of a real decommissioned bridge and a full-scale model built at the Transport Research Laboratory in Great Britain.

Full scale testing to destruction. Cintec reinforcement is revealed following collapse o f inner masonry ring at over twice the unreinforced maximum loading

Reaction wall testing in collaboration with the European Commission at the Joint Research Centre (jRC) at Ispra - Northern Italy.

Physical testing aimed specifically at seismic loading has taken place in the reaction wall laboratory of the Joint Research Centre in Italy. Pseudo-dynamic and cyclic tests were carried out on a full-scale model of part of the cloisters of the Sao Vicente de Fora Monastery, in Lisbon - Portugal. The research was aimed at characterizing the non-linear behavior of stone block struc-tures under earthquake loading and also at assessing the effectiveness of retrofitting Cintec Reinforcement. The retrofitted model dem-onstrated that the continuous bond Cintec Reinforcement performed far better than pre-compression ties.

It was apparent that observed cracking was 'better distributed' within the structure. The tests provided strong evidence for the applicability and effectiveness of such a kind of retrofitting in terms of deformation capacity and strength of the model.

The University of Southampton in Great Britain has also undertaken practical testing. Shaking table tests were performed to investigate the behavior of masonry block work structures with and without Cintec stitching reinforcement. The conclusions revealed the stitching reinforcement *'significantly increased the performance of masonry structures under horizontal dynamic loading'.*

Tried & Tested

The Shaking Table Study concentrated on cellular buildings with masonry facades. Cintec Lateral Restraints increased the failure load by a factor of more than two.

A

Following An Earthquake

The structural damage caused by an earthquake in an urban area is often compounded by ensuing fires. Many properties which have survived the initial shock may subsequently be destroyed. Destructive fire test trials conducted at the Building Research Establishment (BRE) in Great Britain have compared the cementitious Cintec Reinforcement against both mechanical expansion and resin systems of reinforcement. All were subjected to temperatures of 1200 °C. In these tests the resin ties failed on average after 1/2 hour heat exposure. Metal expanders were capable of longer periods of resistance which could exceed 1 hour, but could fail prematurely if they were not sufficiently torqued. The best results were achieved by the Cintec Reinforcement anchors which were capable of at least 2 hours resistance. This extra-time may prove sufficient in maintaining the structural integrity of a building while a potentially devastating fire is brought under control.

Pull out tests revealed that Cintec still performed within specification even in the walls worst effected.

Trial by fire

Cintec reinforcements were installed in the 200 year old Fullers Brewery in London (right). A fire however, subsequently destroyed the interior of the building. Although subjected to extremely high temperatures the reinforcements remain intact, and pull out tests revealed that they still performed to their original design specification. Had a resin alternative been specified, they may well have melted. Where Cintec reinforcements had been installed there were no cracks in the structure. Their earlier performance ensured they were used to consolidate brick work delaminated by the heat and allow internal repairs without the risk of collapse

Case History: Newport Heights Elementary School, Washington State.

Newport Heights Elementary School, Washington, was built in the early 1960's, well before modern U.S. seismic codes were in place. Although the one-storey buildings have a well designed and well built roof system, the entire exterior envelope was composed of concrete masonry (CMU) infill walls. These walls were neither anchored nor reinforced to the main structural frame for in-plane or out-of-plane forces. Furthermore, the hollow cells of the CMU were completely ungrouted. Reinforcement was clearly necessary to avoid the risk of collapse during a seismic event.

To maintain floor space, steel plate "backer bars" were chosen to reinforce the walls. These were anchored to the floor slab and the roof structure with standard fasteners. The connection between the "backer bars" and the hollow CMU required a more custom connection; an anchor that could be set through a small hole into a hollow cell that could then be filled with grout (while not filling the entire vertical cell) and finally, anchored to the "backer bars" with a head screw. Cintec developed an anchor specifically tailored to the project's needs. A number of anchoring devices had previously been tested but only Cintec met the load requirements. Their swift and smooth installation convinced the school district and the general contractor that Cintec reinforcements were the right choice.

In North Cintec is also involved in seismic projects for Pacific Gas & Electric and the Mission of San Juan Capistrano.

Case History: Christ Church Cathedral

In 1989 a powerful intraplate earthquake occurred only 14km (8.7 miles) below the surface of Newcastle in New South Wales, Australia. Its effect on the provincial cathedral was considered so extensive it was feared large sections would need to be demolished and rebuilt. However, the consulting engineer involved in its refurbishment became aware of the Cintec Masonry Reinforcement system previously unknown in Australia.

Following extensive trial installations and testing both engineers and archi-tects agreed that it was the only viable system for reinforcing the Cathedral.

The prime aim of the structural design was to turn the build-ing into a ductile structure, lack of ductility being the main cause of catastrophic collapse of buildings during earthquakes. A two-dimensional finite element analysis was carried out in order to generate a computer model which would predict the behaviour of the structure during possible future seismic activity. Reinforcement lengths, diameters and locations were also modelled in order to achieve the most appropriate design. In total 3770 metres (12,400ft) of reinforcement was installed in accordance with the updated 1993 Australian design code for earthquake loading.

A

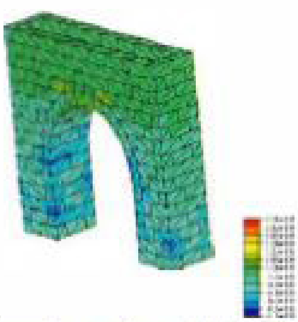
A twenty metre (66') vertical Reinforcement being placed by crane. This project saw the installation of horizontal reinforcement of up to 32 metres (105') in length, Cintec's longest to date. Small video cameras and fibre optics were used to verify the integrity of each drill hole along its full length.

Case History: The Mosque of al-Ghuri

It is accepted that all numerical modelling of masonry structures will inevitably present a somewhat idealized representation. In practice, a degree of pragmatism and engineering judgement is also required, especially where localized repairs are involved. The reinforcement of al Ghuri Mosque in Cairo, Egypt, is a case in point.

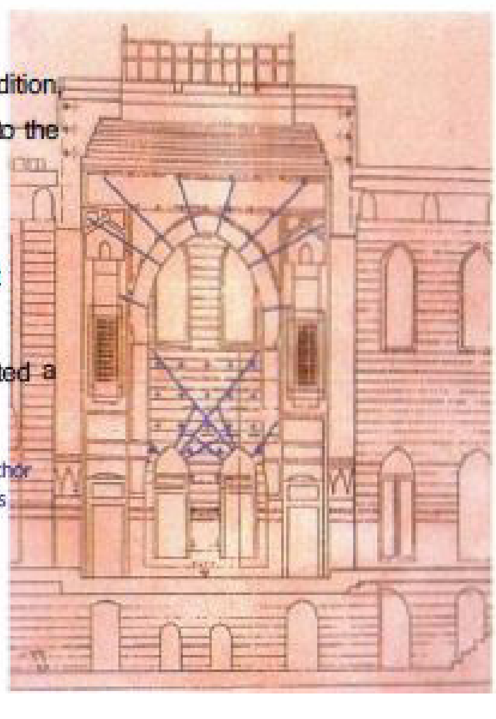
In 1992 an earthquake of approximately 5.9 on the Richter scale occurred 30km (18.5 miles) to the south-west of Cairo. The epicentre was near the surface and its relatively high frequency meant that damage to low structures of up to five storeys was intensified. Built in 1504AD (909AH) the mosque of Sultan al-Ghuri was left in a very delicate state of equilibrium. Despite having survived for 500 years, earthquakes and neglect had brought the structure to the point of collapse. Typical damage included separation of walls at right angles resulting in vertical cracks, spreading of the arches and dropping of voussoirs, settlement of the floors, failure of roof to wall connections and a loss of integrity of the walls construction.

A f,ve metre (16' 5") long vertical reinforcement being installed at roof level.



An archway is computer modeled to evaluate potential seismic loading.

Working in conjunction with The High Council of Egyptian Antiquities, Cintec Reinforcement was extensively introduced to restore structural integrity and provide additional ductility to the building. Anchors up to 12 metres (39ft) long served to stiffen individual walls which in general comprised two facing skins filled with a core rubble. Longitudinal ties in each of the stone facings in the walls above arches serve to resist the thrusts naturally produced by the arch as well as serving to assist the walls to resist subsequent earthquakes. In addition, transverse ties of length equal to the thick-ness of the wall acted as consolidation anchors. Furthermore, Cintec reinforcement connecting the roof structure to the perimeter walls created a diaphragm action.



An engineers drawing details typical anchor placements for the arches and side walls.

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

CINTEC
REINFORCEMENT SYSTEMS
www.cintec.com