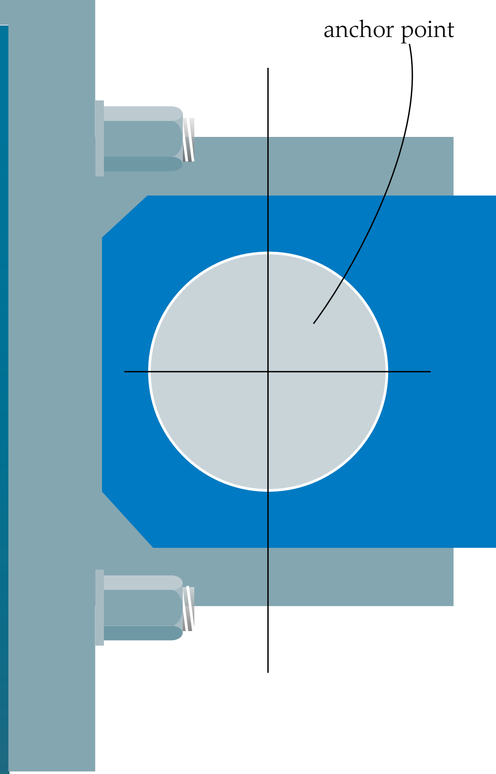
# LUD®

# LOCK-UP DEVICE

## ESSENTIAL PROTECTION FOR STRUCTURES AGAINST SEISMIC, BRAKING AND TRACTION FORCES

# LOCK-UP DEVICE

The Colebrand International Lock Up Device (from hereon referred to as the CI LUD®)is the most widely specified product of its kind in the world. It may be used to strengthen bridges and viaducts, particularly in cases where the frequency, speed and weights of vehicles and trains have increased beyond the original design criteria of the structure. It may be used for the protection of structures against earthquakes and is cost effective for seismic retrofitting. When used in new designs large savings can be achieved over conventional construction methods.




Colebrand International has supplied over 540 CI LUD®s for the Korean High Speed Railway, the largest project ever to use LUD® units. Colebrand International met the rigorous specifications set by SYSTRA, the specialist French high speed rail design consultants.

The CI LUD® has also undergone extensive evaluation by HITEC (Highway Innovative Technology Evaluation Center) to obtain acceptance throughout the United States.

## VALUE FOR MONEY STRUCTURAL UPGRADING

- **Load carrying capacity of the structure is increased**
- **Traffic flow interruption minimised or avoided**
- **Installation costs and tasks minimised**

## COST EFFECTIVE AND SAFE SEISMIC DESIGN FOR RETROFIT AND NEW BUILD

- **Load path through the structure controlled**
- **All substructures operate in unison**
- **Solution costs and tasks minimised**

## ECONOMIC DESIGN SOLUTION FOR NEW STRUCTURES

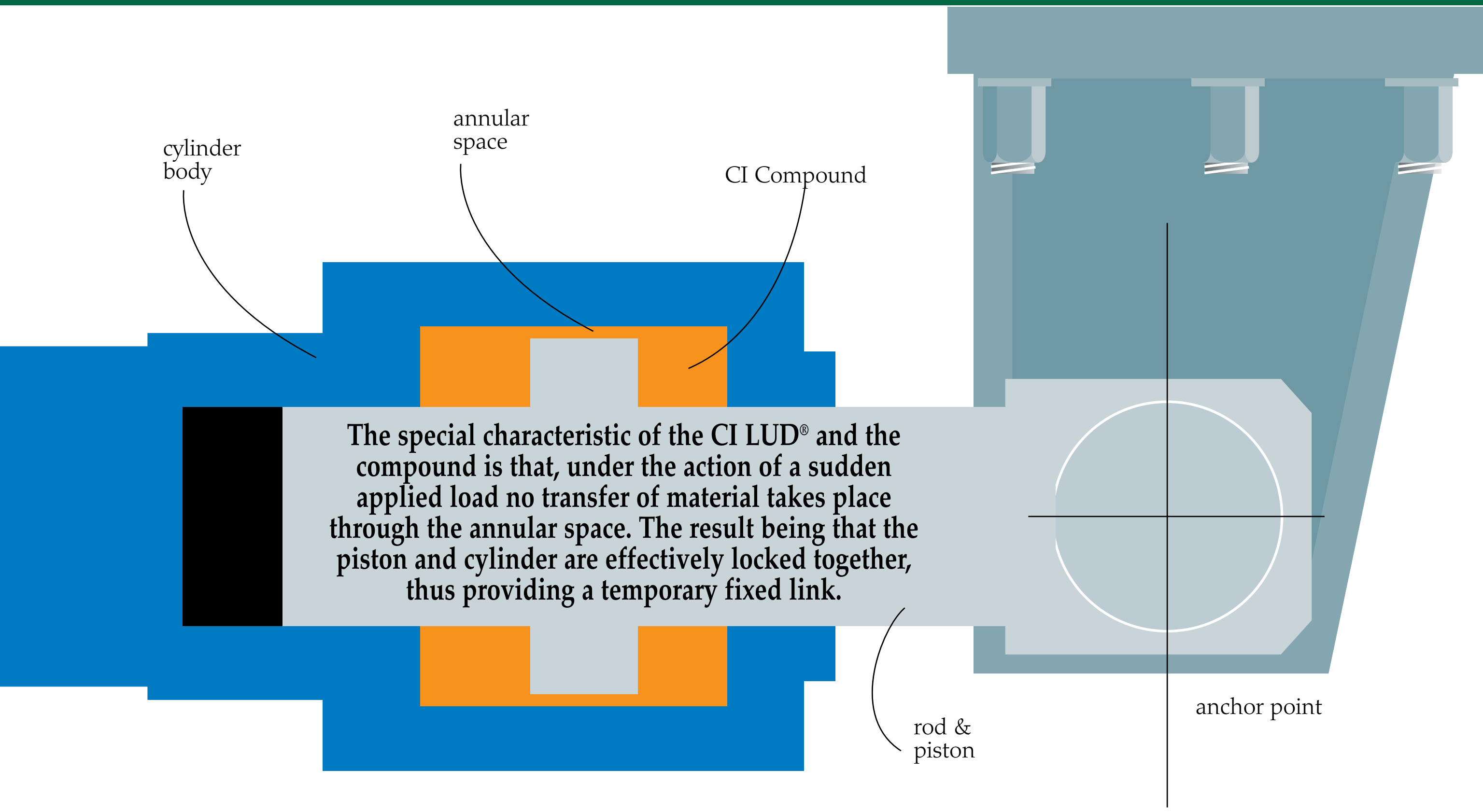
- **Structural member sizes optimised**
- **Ultimate and service limit states considered equally**
- **Overall costs minimised**

The primary purpose of the CI Lock-Up Device is to provide a temporary rigid link between the deck of a bridge and its supporting abutments and piers so that under fast acting and short duration seismic, traction, braking or collision forces the load is shared between the supports. Under slow acting thermal, shrinkage or creep movements the CI LUD® no longer acts as a rigid link and moves with the deck.

The CI LUD® is a precision engineered device which comprises of a sealed cylinder and piston. The cylinder is packed with a specially formulated CI Compound.

Under slow structural movement due to thermal expansion or contraction, the CI Compound migrates from one side of the piston to the other as illustrated in the diagram. The piston slides inside the cylinder experiencing very little drag resistance compared to the much larger forces which would arise if this movement did not take place, as with a permanently fixed link.

The design of the CI LUD®s, quality of manufacture, and mode of operation ensure that the LUD®s are virtually maintenance free.




# The Colebrand International LUD® Range

## All Colebrand International Lock-Up Devices are custom made to suit design engineer requirements

**Standard LUD®**
May be used for the protection of structures against the effects of seismic, braking and traction forces and other suddenly applied horizontal loads.

**Extended Range LUD®**
Offers outstanding load/displacement characteristics under seismic loading and drag force performance over the temperature range -40°C to +50°C.

**Crawl Connector**
Intended to be used for the protection of structures against the effects of intermittent uni-directional loads such as may be applied by vehicles / trains when braking or accelerating.

# APPLICATIONS

CI Lock-up Devices, known in some markets as Shock Transmission Units, have provided protection to road and rail bridges for more than 25 years. Lock-Up Devices allow the load path through a structure to be controlled so that the components of the substructure operate in unison.

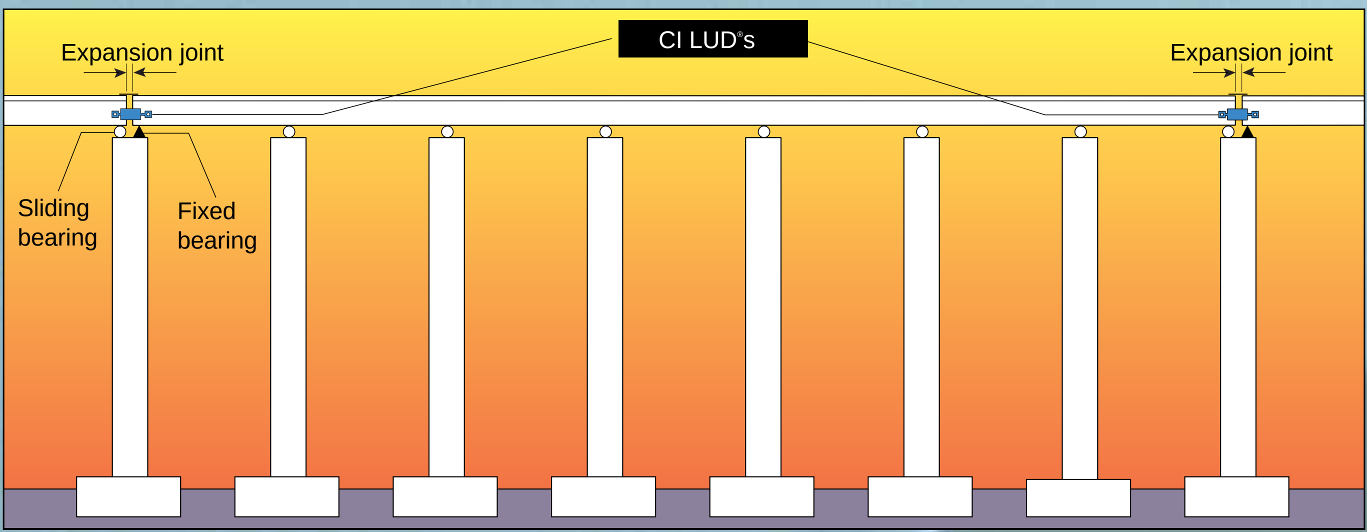
Typically, for new build, structural upgrade or seismic protection projects the CI LUD®s may be installed between either the superstructure deck and its supporting piers/abutments or between adjacent deck sections.

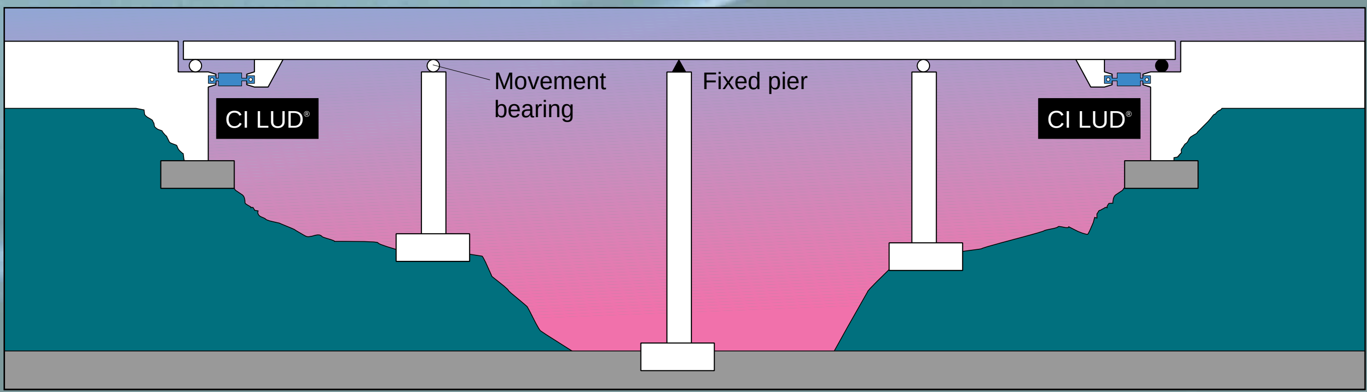
Examples of typical deck to deck and deck to pier arrangements are shown below.

**Multi-span Bridge Decks under Seismic Loading**
The longitudinal forces generated in a bridge deck subjected to earthquake loads are a function of the deck mass and are normally far in excess of those forces caused by traffic acceleration and braking. The seismic forces would normally only be resisted at the location of the fixed bearings, but with the addition of LUD®s to the structure these forces can be shared between all supports where the LUD®s are installed. During a seismic event, protection to the structure can therefore be provided economically by LUD®s which temporarily lock and then permit the structure to expand/contract normally after the shock has passed and they revert to their passive state.

**Strengthening of Existing Structures**
Due to ageing, increases in traffic loading and density and /or code revisions, many existing bridges now require strengthening works to be carried out.

CI LUD®s provide a means of strengthening existing bridge substructures at far lower cost than by conventional structural methods. Further cost savings result from the owners ability to keep the structure open during installation. This contrasts with the disruption to traffic that often occurs when more conventional strengthening methods are employed.



# NEW BUILD

On new structures, the force sharing made possible by CI LUD®s allows a continuous deck structure to be designed lighter, giving potential savings in pier sizes and foundations.

CI are at the forefront of the development of LUD®s and their derivatives, and following the completion of two years of testing with HITEC in the USA, have provided key technical information to facilitate the incorporation of LUD®s into the AASHTO Bridge Code.

# SEISMIC RETROFITTING

The introduction of revised seismic design codes and subsequent structural design assessment often dictate that the structure be upgraded to cater for an anticipated earthquake. This upgrading, by load sharing, may be economically achieved by the installation of CI LUD®s. This does not require any amendment to the structural bearings and hence expensive jacking of the structure is not required.

The CI LUD® also provides an engineering solution to seismic retrofits rather than the use of cable restrainers.

# THE CI LUD® IS MAINTENANCE FREE

The CI LUD®s have been specifically developed to require minimal maintenance. All units are galvanised to BS5493/BS729 followed by CI's own paint finish. Gaiters are the only part of the device that requires regular inspection every five years.

## COST SAVING
STRUCTURAL UPGRADING OF HIGHWAY STRUCTURES TO MEET EU LOADINGS

## COST EFFECTIVE
SEISMIC RETROFITS

## COST SAVING
RAIL STRUCTURE UPGRADES

## COST EFFECTIVE
NEW STRUCTURES IN SEISMIC ZONES

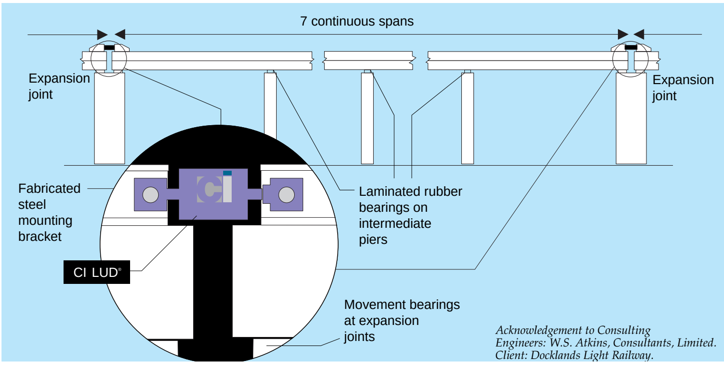
## COST SAVING
NO ROAD CLOSURES

# SIGNIFICANT PROJECTS

## Docklands Light Railway, London, UK.

The upgrading of the Docklands Light Railway with heavier and more frequent trains necessitated the strengthening of many existing viaducts to accommodate the greater braking and traction loads. The diagram shows one of several seven-span deck viaducts, continuous between expansion joints, which would have suffered critical substructure overload with the increase in traffic.

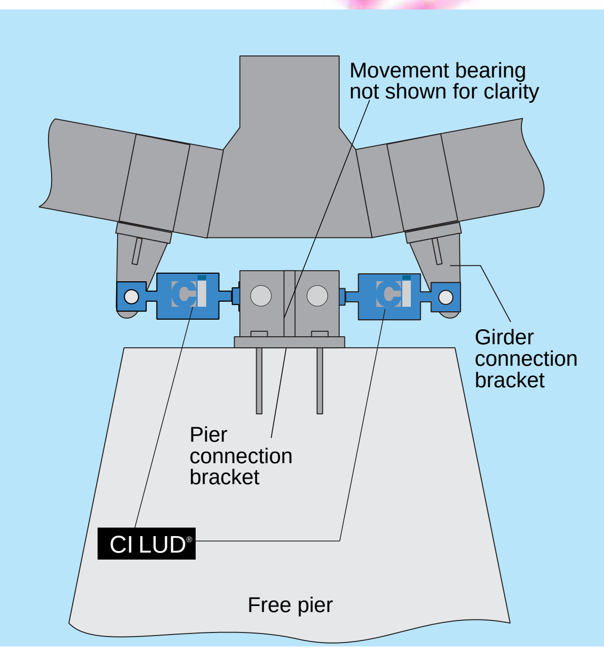
Train traction and braking loads were shared amongst the slender piers, most of which support the deck via rubber bearings. CI LUD®s were installed at rail level linking the joints between adjacent seven-span viaducts. When the increased longitudinal traction and braking load is applied to one particular viaduct, the load is transmitted and shared with the adjacent unloaded viaducts. Installation of the CI LUD®s eliminated the need for costly strengthening of the piers and foundations and allowed the train service to continue without interruption.



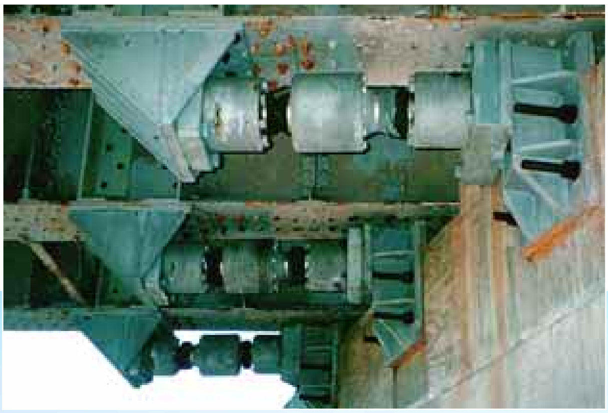

*Acknowledgement to Consulting Engineers: W.S. Atkins, Consultants, Limited. Client: Docklands Light Railway.*

## Mekong River Bridge

The Mekong River Highway Bridge which links Thailand with Laos, is a multispan viaduct. LUD®s were installed to transmit earthquake forces into a free pier, thus significantly reducing the forces required to be taken by the fixed pier.




**Interstate 24, Illinois, USA. Seismic Retrofit**
Re-assessment of an existing structure, which is near to the New Madrid fault system, required seismic retrofitting to meet current design specifications. The bridge is a three span continuous steel girder structure with concrete abutments and piers. One line of fixed bearings resisted longitudinal seismic forces.
The seismic upgrading was achieved by the addition of four CI LUD®s which were retrofitted to the structure without any disruption to the traffic flow.

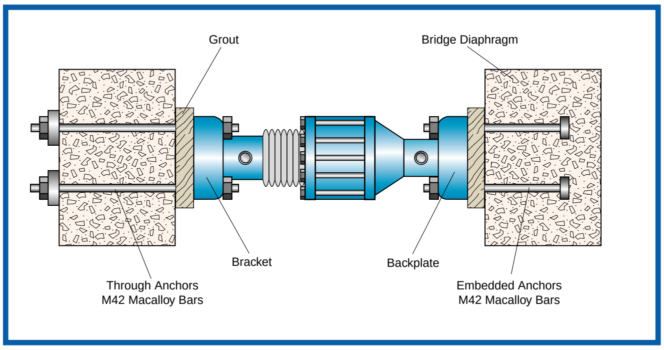


**Neath Railway Bridge, Wales**
The piers of this Victorian rail bridge were found to be unable to take the horizontal braking/traction forces of modern trains. The installation of CI LUD®s between the deck and the abutment was found to be a cost-effective solution. Due to the curvature of the bridge the LUD®s are connected to the brackets using ball joint connections rather than the conventional clevis arrangement.

# THE KOREAN HIGH SPEED RAIL PRO

## THE WORLDS LARGEST PROJECT TO USE LUD® / LONGITUDINAL LOAD TRANSFERRING DEVICES

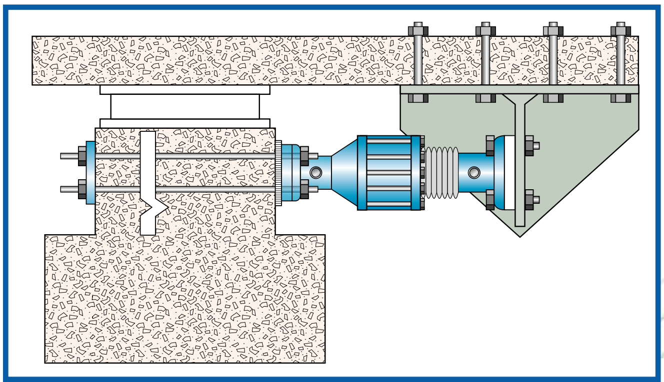
## OVER 540 LUD®s/LFTs HAVE BEEN SUPPLIED TO 19 BRIDGES ON THE PROJECT INCLUDING ONE VIADUCT NEARLY 7KM LONG




### DECK TO DECK UNITS

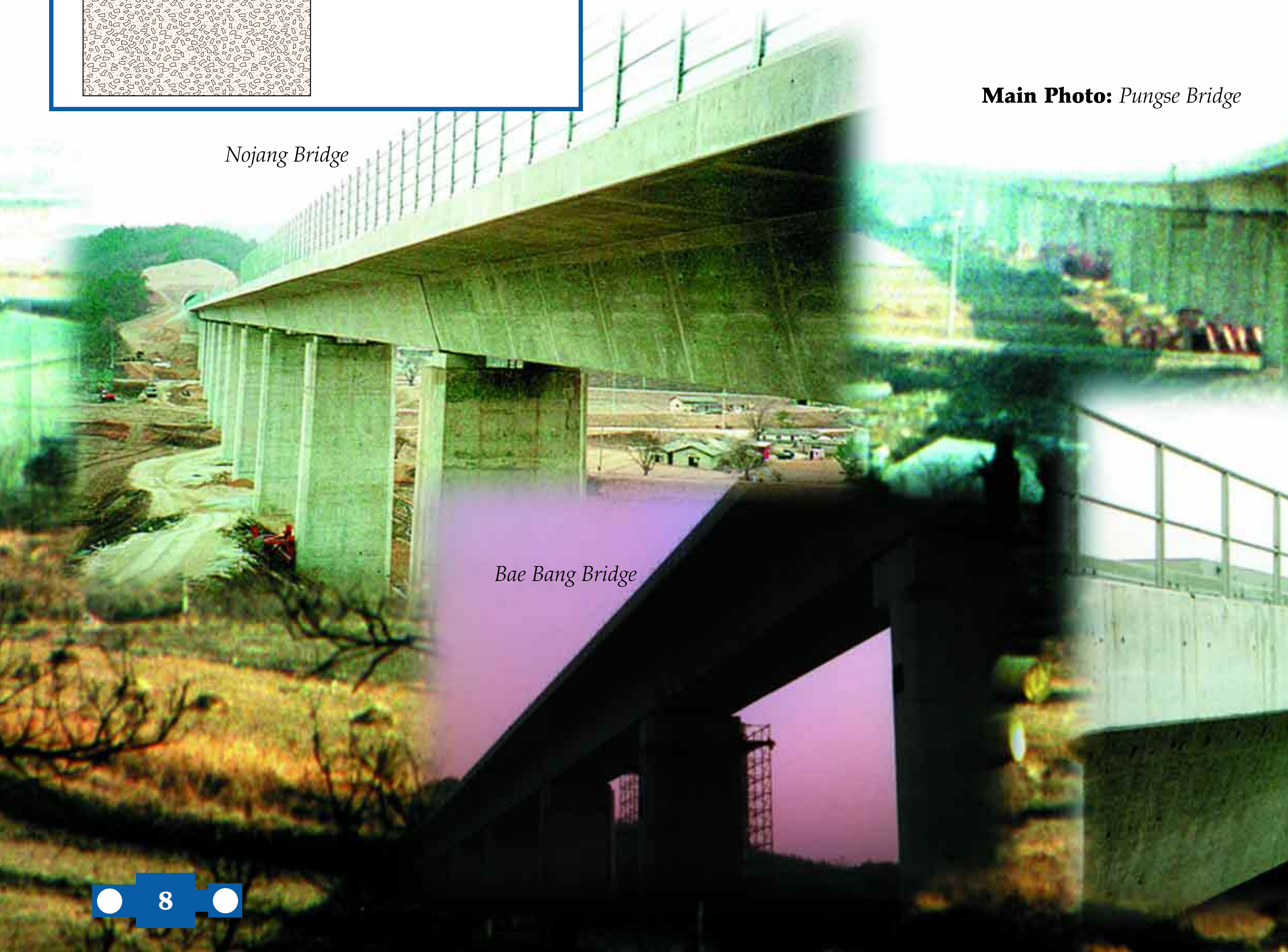
The units were placed in these positions to transfer the braking forces across the expansion joints between the continuous spans, with two units placed parallel to each other at every location.

Load capacity of each unit is 1750kN and to allow the bridge to expand and contract, the standard LUD® has a stroke length / movement capacity of ±60mm. These units must resist a force of 1750kN through a temperature range of -25°C to +40°C. and only allow a displacement of less than 10mm



### DECK TO PIER UNITS

The LUD®s were used in the deck to pier position between the bridge soffit and the top of the pier to transfer braking loads into the free piers near the station areas.



**Main Photo:** *Pungse Bridge*

*Nojang Bridge*

*Bae Bang Bridge*

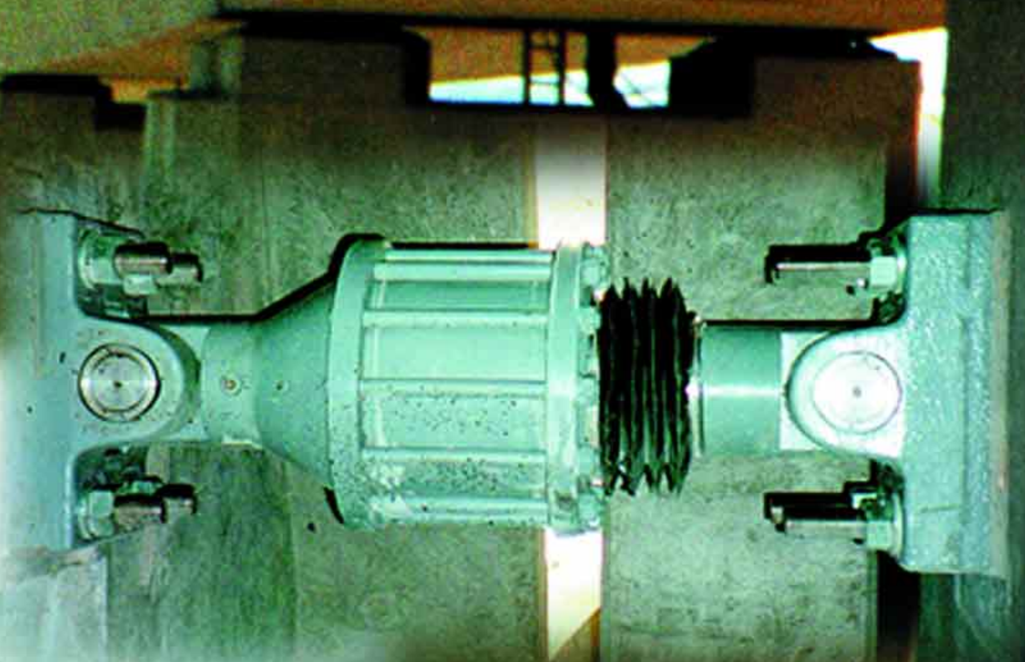
# JECT

The Korean High Speed Railway provides an express link between the capital city Seoul and the southern sea port of Pusan, a distance of 350km

# CI LUD® LOCK-UP DEVICE

## CHOSEN BECAUSE:

- CI LUD®s provide a cost effective method of transferring the very large train braking forces throughout the structures.
- The CI LUD® can be easily installed during construction of the structure, preventing delays to the construction sequence.
- Minimal maintenance is required on the LUD® after installation and throughout the life of the bridge.
- The CI LUD® has passed the rigorous test procedure set by SYSTRA and is approved for use on the KHRC project.
- CI has the experience, expertise and manufacturing capability to supply both the quantity and quality of product required by the KHRC.



*Yonje Bridge*

# SIGNIFICANT PROJECTS

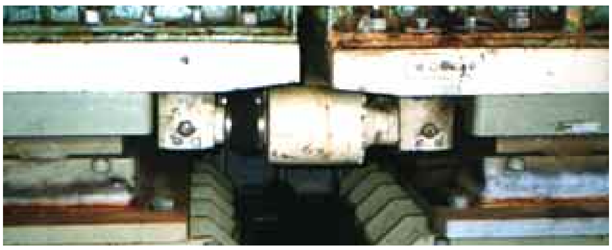
**Arthur Laing Bridge, Vancouver**

This prestigious multi-span structure was seismically retrofitted using CI LUD®s to protect the viaduct that connects Vancouver with the international airport.

The design was carried out by Sandwell Consultants, Vancouver and included the supply of 2100kN and 700kN LUD®s, two of which were proof tested by an independent laboratory before installation.

**Putney Bridge, London.**

This Victorian bridge, which carries the District Line of London Underground over the River Thames, was upgraded and repaired as it had come to the end of its design life. The repairs involved considerable works to the steel deck structure, the installation of new bearings and the inclusion of sixteen 500kN LUD®s. The LUD®s were incorporated into the design, being fitted in series with the new bearings, to transfer braking forces into the abutments, to ensure the cast iron piers in the river were kept in compression. This avoided the need for expensive works in the river, which has a tidal range of nearly 6 metres, and thus provided a very cost effective solution to the engineering problem.



**Chicago Beach Hotel, Dubai.**

This new hotel development, built on a man-made island off the coast of Dubai, is connected to the mainland by a seven span steel composite bridge that also carries all the services for the hotel complex from the mainland.

This bridge was therefore designed to withstand earthquake forces and four 2500kN LUD®s were fitted to the structure. However, the fixity of the LUD®s was further complicated as one of the abutments was also the main wall of the onshore plant room. Thus an elongated arm device had to be manufactured to allow the device to be fitted through the plant room wall, connecting to the structure roof.

**Cattawade Bridge, Essex, England.**

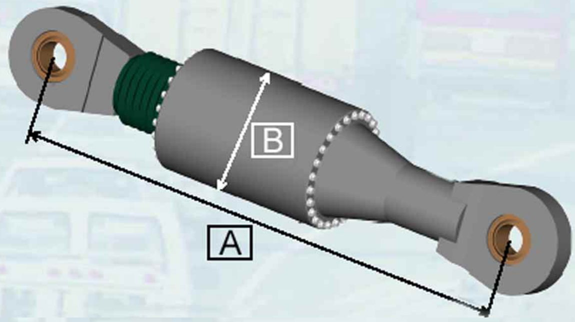
As part of an on-going strengthening programme to this road bridge in Essex, CI supplied and installed LUD®s with an innovative bracket design. The units were used to transfer the braking forces across the expansion joints between the bridge decks and into the abutments. With the large distances between the crossheads and the unusual layout, CI designed and patented an extended arm arrangement for the bracket, incorporating a sliding bearing.

# SIGNIFICANT PROJECTS

**Tay Road Bridge, Scotland.**
CI LUD®s were retrofitted to the Tay Road Bridge to reduce the effect braking and traction loads on the bridge piers. The loads were transferred between the decks by two 300kN units installed across the expansion joints of the bridge. The road was kept open during installation of the LUD®s and major strengthening work on the piers was avoided.

**Kuala Lumpur Mass Transit Railway, Malaysia**
CI supplied 500kN LUD®s to control braking and traction loads on the Light Rail Transit System. The 12km rail system links Ampang on the outskirts of the city to Jalan Ismail in its centre.

# DIMENSIONS AND DESIGN LOADS




### Nominal Design Loads and Dimensions of Single-Piston Units

CI design units to meet a specific requirement. As a guide, the table, right, indicates typical sizes and weights for CI LUD®s. Units are assumed to be in mid-stroke; dimension A varies by ±50mm to cater for this range of expansion or contraction movement. Greater or smaller ranges can be readily accommodated.

### Design Loads

The table gives the working loadings for nominal ranges of the CI LUD®s. You may wish to specify an ultimate load for the units you require and our design team will be happy to discuss this with you.

The working range of the unit defines the maximum impact force which can safely be transmitted, whilst the length of the transmission rod can be varied to suit the long-term axial movements between the fixing eyes attached to the separate structures

| Unit Size kN | Dim.A mm | Dim.B mm | Weight kgs |
|---|---|---|---|
| 100 | 400 | 110 | 8 |
| 200 | 470 | 145 | 28 |
| 300 | 555 | 172 | 40 |
| 400 | 555 | 206 | 65 |
| 500 | 600 | 208 | 75 |
| 600 | 630 | 240 | 100 |
| 750 | 730 | 265 | 130 |
| 1000 | 800 | 300 | 200 |
| 1250 | 850 | 325 | 260 |
| 1500 | 900 | 385 | 300 |
| 1750 | 950 | 410 | 350 |
| 2000 | 1000 | 450 | 500 |
| 2500 | 1050 | 460 | 650 |
| 3000 | 1200 | 550 | 850 |

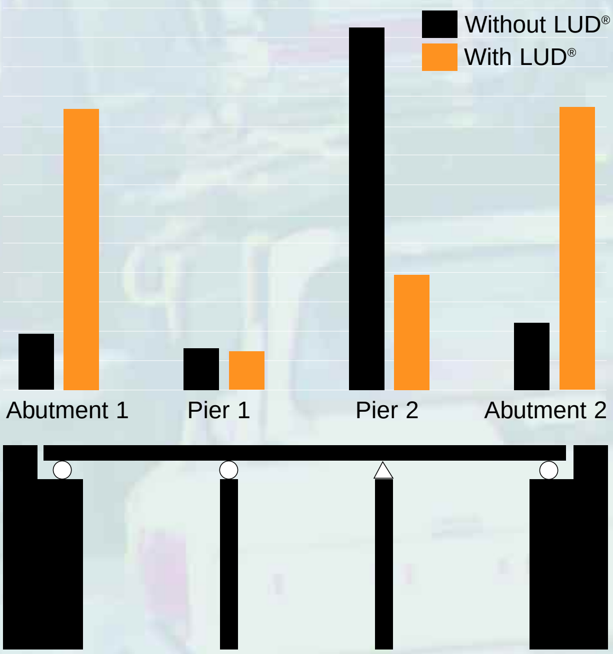
### Design Considerations

Our engineers use state of the art design programmes and drafting capability to ensure that each CI LUD® is exactly suited to its particular application. We request that you complete a CI Design Questionnaire to enable our our design team to provide a working drawing, specification and price guide for a specific project.

The CI LUD®s may be used to cater for forces that are not acting axially along the structure. Our design team will be pleased to advise.

# BSA

Point Elastic Seismic Forces at the Superstructure




CI has developed a Bridge Seismic Analysis Program which allows bridge engineers to analyse the performance of structures under seismic loading. Comparison of moments and forces generated both with and without CI LUD®s enables the benefits of the design to be appreciated. The diagrams illustrate the shared moments on a bridge fitted with one LUD®.

The BSA program evaluates the structural characteristics of the bridge to AASHTO Code, providing the user with the following information concerning the bridge's behaviour under seismic activity:

- **The principal period of bridge oscillations**
- **Seismic loading intensity and elastic seismic displacements of the bridge deck**
- **Elastic seismic moments in the bridge deck and supports**
- **Elastic seismic forces in the bridge deck and supports**
- **Point elastic seismic moments and forces at head and foot of the substructure columns.**

The BSA package provides a clear graphical interface for quick and effective analysis of a bridge's vital parameters.

# SERVICES PROVIDED

CI LUD®

LOCK-UP DEVICE

CI provide a comprehensive engineering support service to ensure that for all projects the optimal LUD® solution is achieved.

This service comprises:

Full engineering support to develop the appropriate LUD® specification together with the project designer.

Design of LUD®s with brackets and fixings.

The manufacture and supply of LUD®s with brackets and fixings all in accordance with Quality Assurance procedures to BS EN 9000.

Testing of LUD®s to demonstrate that project specifications are achieved and that quality control standards are sustained.

Instruction and supervision of contractors site personnel to ensure that the LUD®s are correctly installed.

# DESIGN AND TESTING

**Every LUD® application presents a unique set of design challenges. Colebrand International has a wealth of expertise in-house to meet these challenges and provide the client with customised, cost effective designs.**

International bridge engineering projects in the 21st Century present the consulting engineer with the ever more demanding quest to find solutions to often conflicting design constraints such as elegance, robustness, seismic resistance and above all, economy. CI's team of engineers has a wealth of experience in producing bespoke solutions to such problems utilising the special properties and proven advantages of the LUD®.

CI provides bespoke solutions in the case of retrofit projects. These take full account of any constraints which, for example, may arise as a result of the structures geometry, method of construction and accessibility for implementation.

# CASE STUDY

In Suffolk County, New York State, USA the State Structural Engineers wanted to provide seismic resistance to a four span composite bridge on trunk route CR111 by splicing the centre joint and installing deck-to-deck LUD®s at the two intermediate joints. The LUD®s therefore link the adjacent spans together whilst still enabling thermal movement to take place unhindered.

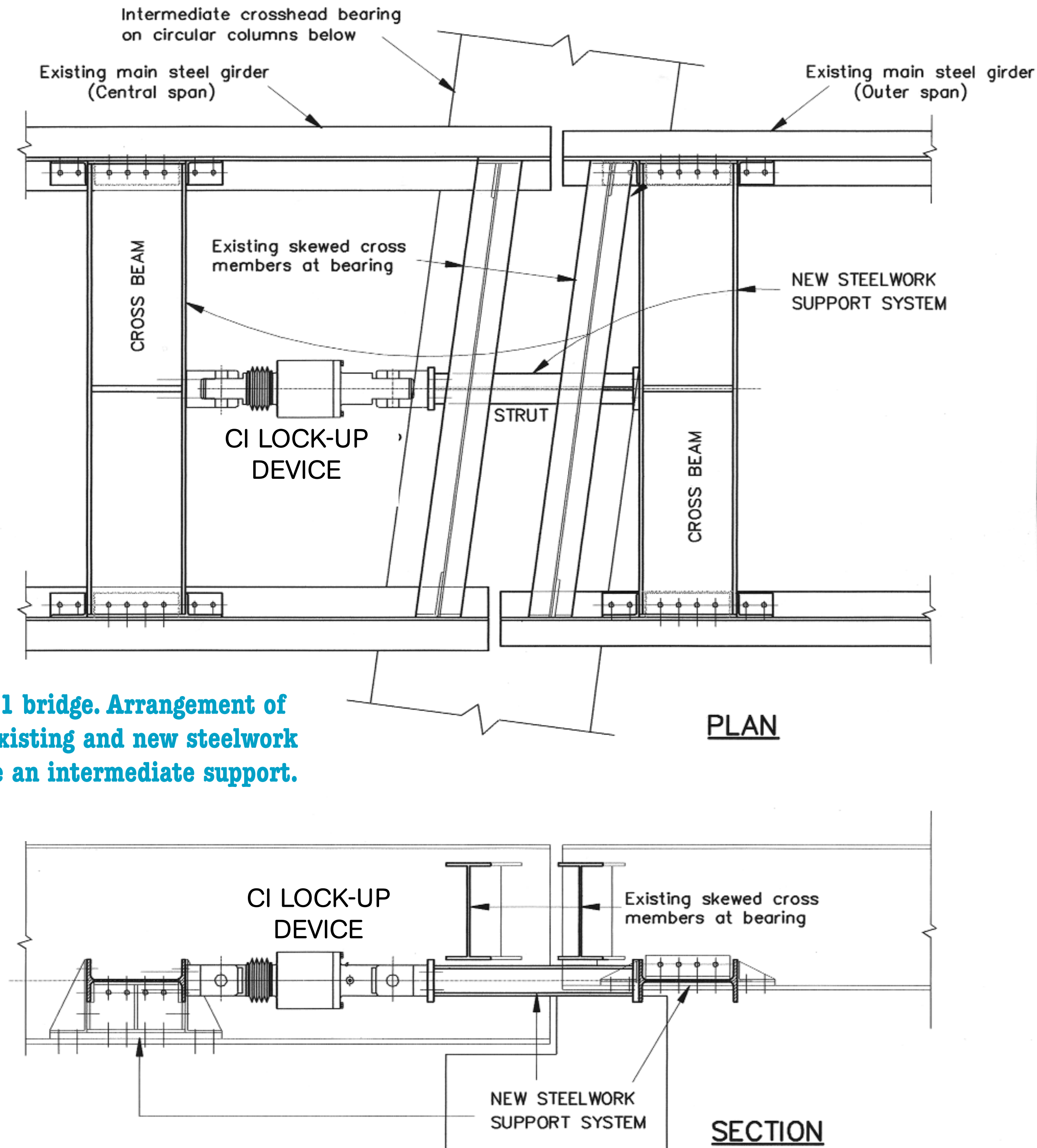
The bridge, in fact, consisted of two virtually identical four span bridges side by side on an 8-degree skew, one carrying the eastbound carriageway, the other the westbound. Each bridge deck comprised seven equi-spaced steel plate girders carrying an in-situ concrete top slab. The two outer spans and two central spans were of length 11 metres and 23 metres respectively, carried on central and intermediate supports comprising circular concrete piers and crossheads. At the intermediate supports, where the LUD®s were to be installed, a change in girder depth occurred resulting in a step in the flange soffits which was accommodated in the plinths to which the sliding bearings were mounted

Fixed between the plate girders were stiffening cross members, which were skewed to the main girders at the intermediate supports.

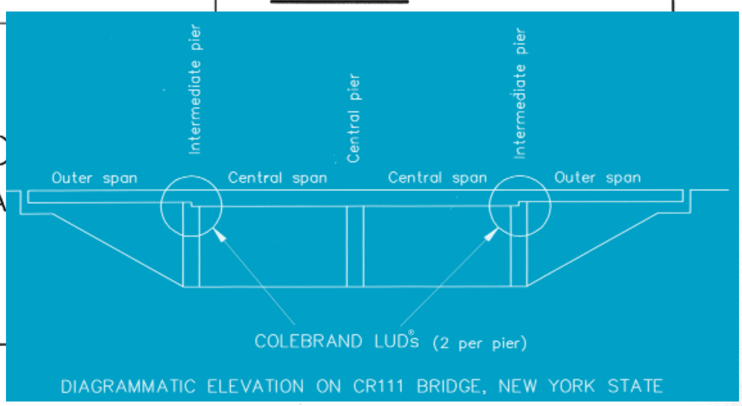
On the face of things, a considerable challenge was presented in finding a suitable way of mounting the LUD®s within an initially unpromising and complex arrangement.

Working in close collaboration with the State Transport Department however, CI's Engineers developed an innovative system of additional support steelwork consisting of new crossbeams between the girders on both spans either side of the intermediate bearings. The addition of a short longitudinal strut to one of the crossbeams then reduced the excess distance between the new crossbeams, thereby facilitating installation of the LUD®.

The State Engineers specified the most stringent criteria for the LUD®s which anticipated forthcoming developments within national research programmes and engineering design codes, both of which are likely to reflect the latest thinking of the North American bridge engineering community. These criteria have been established by HITEC - the Highway Innovative Technology Evaluation Center in Washington DC. HITEC parameters account not only for severe operating conditions that may be encountered during loading but also to ensure that the devices do not inhibit movement due to thermal effects. Full details of the HITEC process and the results obtained from the relevant LUD® can be seen in the following section, Performance Testing.




**CR111 bridge. Arrangement of the existing and new steelwork above an intermediate support.**



# PERFORMANCE TESTING

**CI LUD®s are frequently subjected to full-scale testing to demonstrate that they meet specifications. Typical is the rigorous HITEC test regime described here. The robust nature of the CI LUD® is clearly shown in the results of this and other test programs. certified independent test certificates are available on request.**

## CI and HITEC

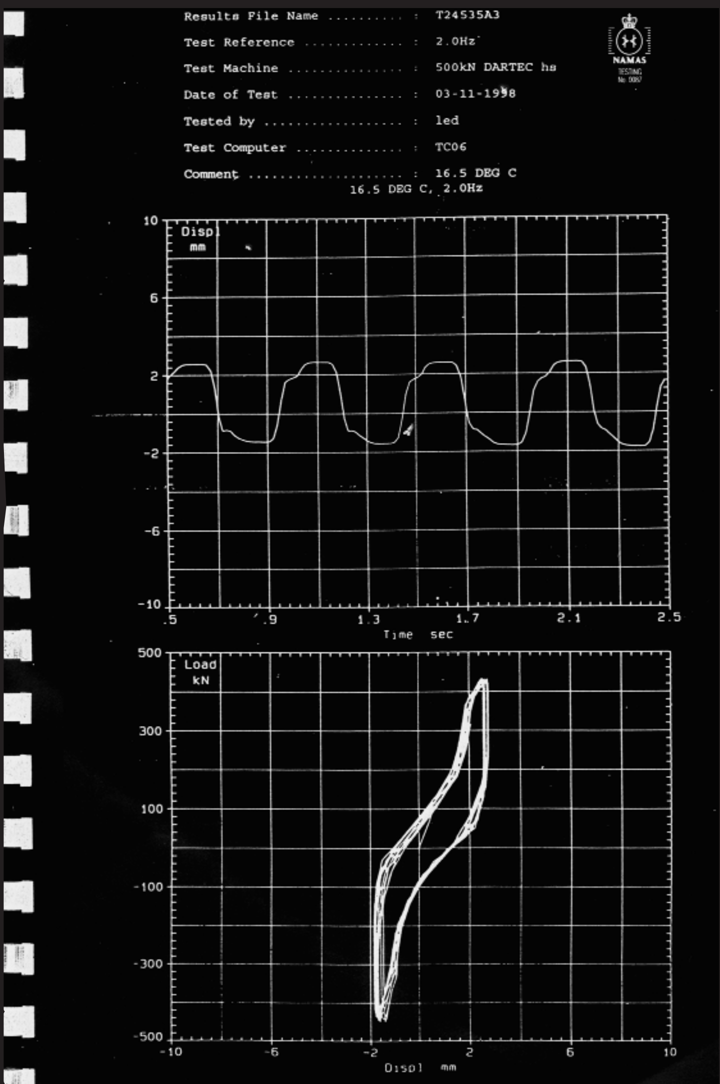
The Highway Innovative Technology Evaluation Center (HITEC) is an organisation created by the American Society of Civil Engineers (ASCE) to bring together diverse groups within the civil engineering community to 'facilitate, integrate and coordinate' common solutions to complex research challenges facing the civil engineering profession.

In order to evaluate the CI Lock Up Device HITEC formed a panel of seismic experts at Federal and State level together with representatives of seismic research organisations and internationally renowned design consultants.

The panel formulated an evaluation programme which comprised a testing schedule for three separate Lock Up Devices and a series of trial installations within the USA.

The intent of the programme being to demonstrate that the Lock Up Devices will perform as required during their service life and will adequately cope with the extremes of temperature (-40°C to +50°C) that can be anticipated in the USA.

The evaluation programme was successfully completed and the results are presented in a separate HITEC report, available on request.




## HITEC testing

**Test Temperature**
Tests were conducted at -40°C, laboratory ambient and 50°C in order to demonstrate that the LUD®s can be utilised in widely varying climatic conditions.

**Seal wear test.**
Testing was performed to demonstrate the integrity of the LUD® cylinder seal. This seal must be able to withstand movement due to thermal effects over the assumed design life of the unit without leakage of the internal CI compound.

**Cyclic Load Test**
This test was performed in order to demonstrate that the LUD® would function as designed during the application of cyclic loading as may be experienced during an earthquake.

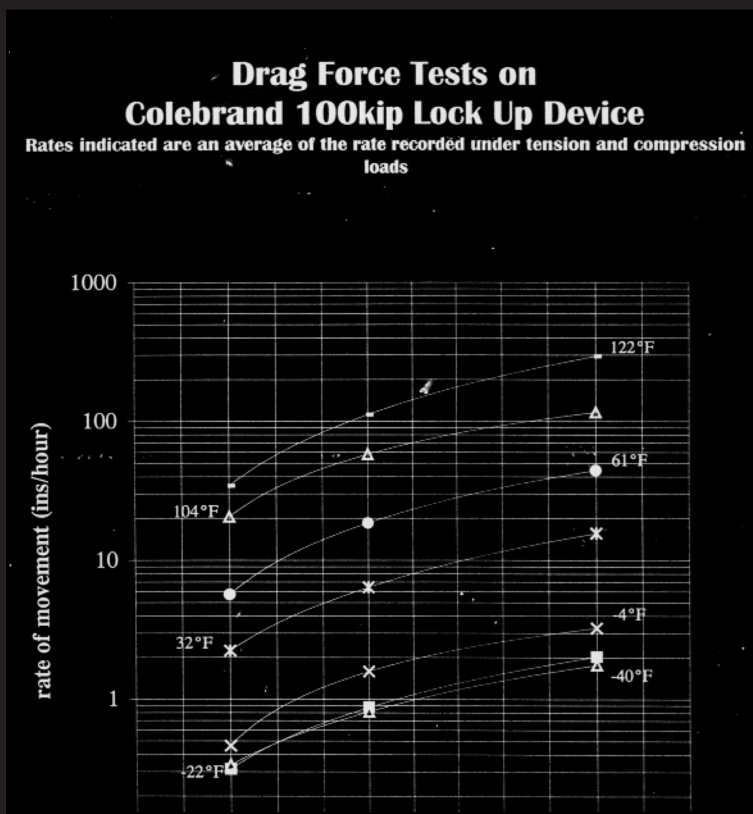
For each LUD® tested, and at each test temperature, varying loading frequencies were applied in order to recognise the variable nature of earthquake loading.

**Drag Load Test**
This testing was performed to determine the load applied to the structure by an LUD® as it moves through simulated daily temperature cycles.

Loads equal to 2%, 5%, and 10% of the rated load of the LUD® were applied, initially in tension and then in compression for a period of ten minutes or until the piston reached the end of its travel. The rate of piston movement was measured and from this the load applied to a structure for a specific rate of movement can be deduced.

**Overload Test**
This test was carried out to confirm that should the rated load of the LUD® be exceeded by up to 50%, the performance and integrity of the LUD® would not be affected.

**Fatigue Test**
This test was carried out to prove the structural durability of the LUD®s should they be subjected to repeated loads such as may be applied by braking and traction forces. The full rated load was applied in tension and compression 100 000 times, this intending to simulate a worst case scenario for service loading over an estimated 75 year service life.



# Testing for the Arthur Laing Bridge project, Vancouver, Canada.

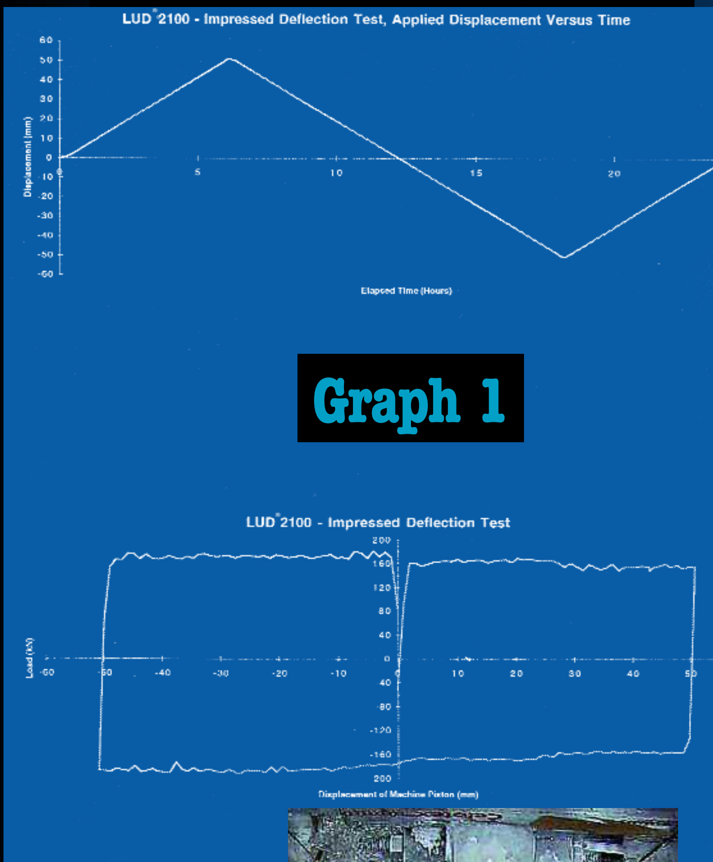
A test regime was specified for this project that used 2100kN and 700kN LUD®s and comprised three tests:

**Impressed Deflection Test.**
The purpose of this test was to evaluate the force resistance of the device at low speeds and to verify the stroke capacity. Acceptance criteria were to travel full stroke and return with less than 10% of the rated load in less than 24 hours. Graph 1 shows the performance of the CI unit.

**Simulated Dynamic Force Transfer Test**
The test objective was to evaluate the stiffness of the device under impulse forces and constant forces. This entailed full positive loading of the device in less than 0.5 seconds, sustaining the load for 5 seconds and then reversing the load in less than 0.5 seconds and holding for 5 seconds. Graph 2 shows the performance of the CI device.

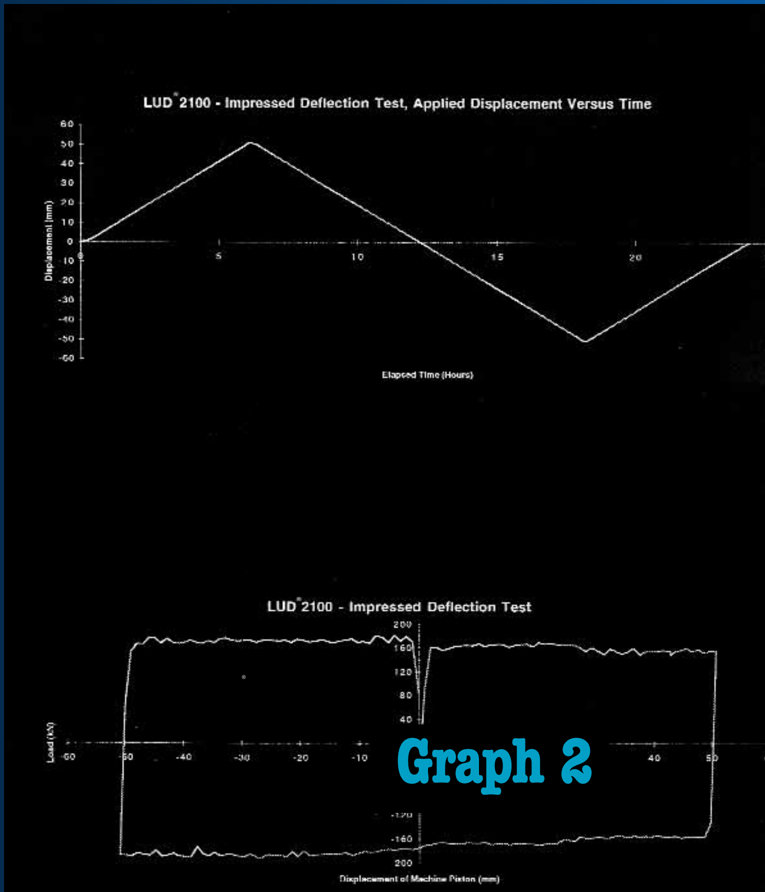
**Simulated Cyclical Force Transfer Test.**
The purpose of this test was to confirm the performance characteristics of the LUD® during simulated seismic loading. Full positive and negative load was sinusoidally applied at 1Hz for 1000 cycles. Graph 3 shows the results.

This test regime has subsequently been specified for other projects.



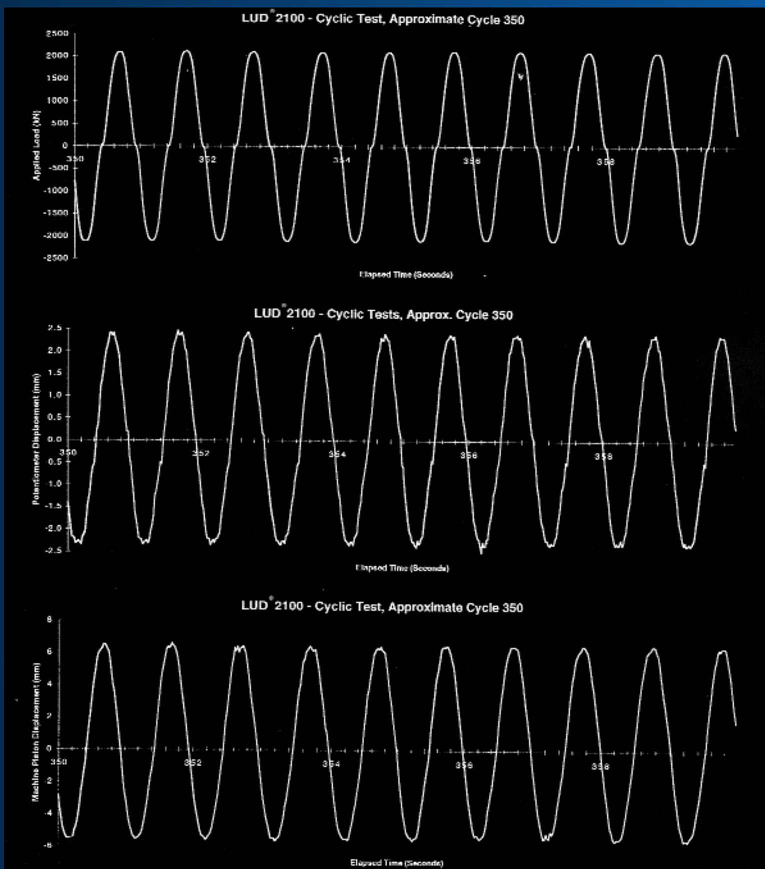

Graph 1

Displacement-Time




Graph 2

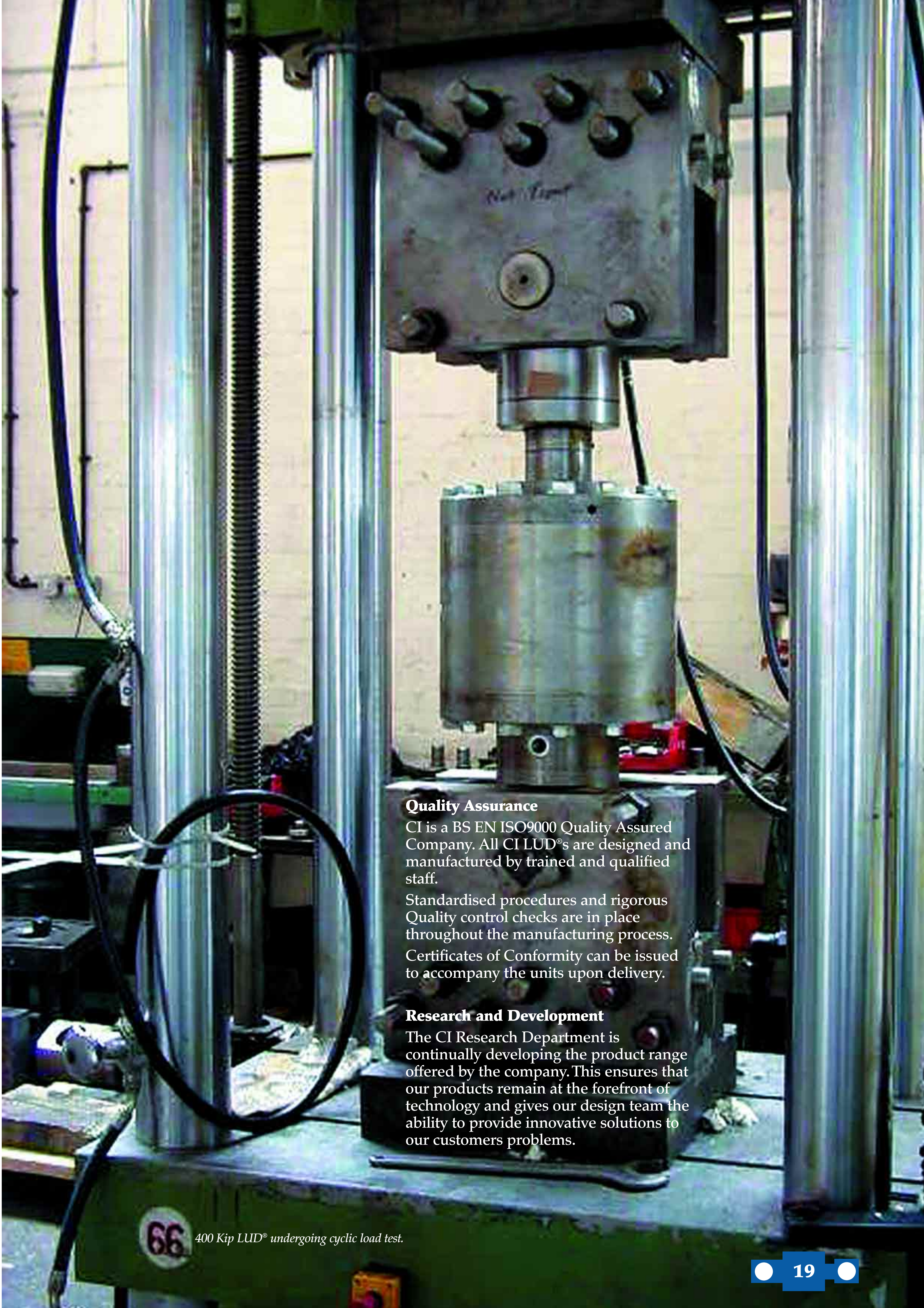
Displacement-Time and Load-Displacement Plots for the 2100 kN LUD®




Graph 3

Results of SCFTT Tests on 2100 kN LUD®

*400 Kip LUD® in environmental test chamber*




### Quality Assurance

CI is a BS EN ISO9000 Quality Assured Company. All CI LUD®s are designed and manufactured by trained and qualified staff.

Standardised procedures and rigorous Quality control checks are in place throughout the manufacturing process.

Certificates of Conformity can be issued to accompany the units upon delivery.

### Research and Development

The CI Research Department is continually developing the product range offered by the company. This ensures that our products remain at the forefront of technology and gives our design team the ability to provide innovative solutions to our customers problems.

*400 Kip LUD® undergoing cyclic load test.*

FM85417
BS EN ISO
9001:2000

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