



### Local On-Sample Strain Measurement (Hall Effect or LVDT)

The GDS Hall Effect or LVDT Local Strain Transducers provide on-sample small strain measurements of axial and radial strain. Accurate determination of soil stiffness is difficult to achieve in routine laboratory testing. Conventionally, stiffness of a triaxial test specimen is based on external measurements of displacement which include a number of extraneous movements. True soil strains can be masked by deflections which originate in the compliances of the loading system and load measuring system. Such equipment compliance errors add to a variety of sample bedding effects to give a poor definition of the stress-strain behaviour of the material under test, particularly over the small strain range.

#### Key Features:

#### Benefits to the User:

Accurate determination of soil stiffness:	True soil strains can be masked by deflections which originate in the compliances of the loading system and load measuring system. Such equipment compliance errors add to a variety of sample bedding effects to give a poor definition of the stress strain behaviour of the material under test, particularly over the small strain range.
Axial and radial deformation measured directly on the triaxial test specimen:	Removes bedding errors or “end effects”.
Small strain measurement:	Recent work has demonstrated that soils can be equally as brittle as rocks and that an understanding of their behaviour at levels of shear strain below 0.05% is very important.
Measurement is taken in the middle third of the sample which is less restrained than the end zones:	Therefore, it is highly desirable that radial and axial deformations are measured locally in this region if realistic deformation moduli are to be found.

#### Tests that can be Performed:

Small strain on-sample local Axial and Radial strain measurement.

#### Technical Specification:

	Hall Effect	LVDT
<b>Range:</b>	+/- 3.0mm	+/-2.5mm or +/-5.0mm
<b>Resolution (using 16 bit data acquisition):</b>	+/- 3.0mm = <0.1µm	+/- 2.5m = <0.1µm , +/- 5.0m = <0.2µm
<b>Accuracy:</b>	+/-0.2% FRO over 4mm range, +/-0.3% FRO over 5mm range and +/- 0.4% FRO over 6mm range	0.1% FRO
<b>Radial caliper weight (based on a 70mm caliper):</b>	46g	74g
<b>Axial apparatus weight (1 off):</b>	16g	26g
<b>Transducer weight (1 off):</b>	5g	20g
<b>Maximum rated pressure:</b>	Up to 2000kPa	Low pressure version for use in water up to 3500kPa High pressure version for use in non-conducting oil up to 200MPa



Fig 1. Axial Hall Effect

### The Hall Effect Axial Strain Transducer

As shown in Fig. 1, a spring-mounted pendulum holds a magnet assembly. This is suspended from an upper pad fixed to the test specimen by pins and bonded to the membrane by adhesive. The spring allows relative motion between the fixing pad and the pendulum without the need to introduce a bearing. This is a very important feature of the device as it guarantees no slack in the system while ensuring that friction remains very low.

The lower part of the gauge consists of a metallic container holding the linear output Hall Effect semiconductor encapsulated in epoxy resin. This is mounted on the specimen by means of a pinned fixing pad (Clayton & Khatrush, 1986).



Fig 2. Radial Hall Effect

### The Hall Effect Radial Strain Transducer

As shown in Fig. 2, the device comprises a caliper similar to that originally designed by Bishop & Henkel (1962) and described in their book "The measurement of soil properties in the triaxial test". This type of caliper has been used for many years to indicate lateral deformation in the triaxial test. The caliper is mounted on the test specimen by means of two diametrically opposed pads fixed to the test specimen by pins and bonded to the membrane by adhesive.

The Hall Effect transducer is positioned across the opening of the caliper where it measures the opening and closing of the jaws. Both the axial and radial devices are designed so that self-weight is partly counteracted by buoyant uplift.

#### Key Features:

Light compact semiconductor chip:

+/- 1V DC Voltage Output:

#### Benefits to the User:

The Hall Effect semiconductor chip is very light, has compact assembly and is compensated against changes in ambient temperature and changes in DC voltage supply.

Can be connected directly to any standard data acquisition system.

### The Hall Effect deformation transducer – explanation of the principal

If a metallic or semiconductor plate, through which current is flowing, is placed in a magnetic field where flux lines are directed perpendicular to the plate and the current flow, the charge carriers will be deflected so that a voltage is produced across the plate in a direction normal to the current flow. This is known as the Hall Effect after E H Hall who discovered the effect in 1879. Hall Effect semiconductors are used widely to measure magnetic flux density. Linear versions of these devices are typically direct current (DC) energised and deliver a DC output which varies linearly with magnetic flux density over a specified range.

The devices have been applied to the measurement of local axial and radial deformation in the triaxial test. The work was pioneered by Dr Chris Clayton and his colleagues at the University of Surrey where they have been used successfully for over ten years.

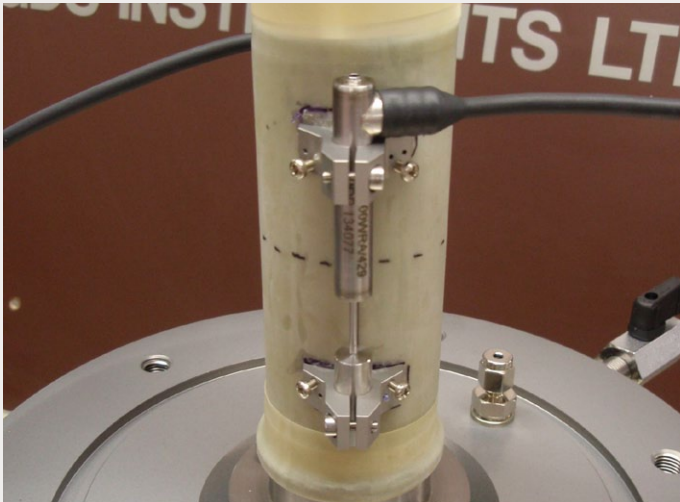


Fig 3 Axial LVDT

### The LVDT axial strain measuring device

As shown in Fig. 3, the axial LVDT is suspended from an upper pad fixed to the test specimen by pins and bonded to the membrane by adhesive. The LVDT armature has a weighted rounded brass end, which rest freely on the lower pad anvil. Aluminium fixing struts may be attached between the upper and lower pads to allow help alignment of the pads when being fixed in place. Once in position, the fixing struts may be removed.



Fig 4 Radial LVDT

### The LVDT radial strain measuring device

As shown in Fig. 4 below, the radial LVDT and caliper is mounted on the test specimen by means of two diametrically opposed pads fixed to the test specimen by pins and bonded to the membrane by adhesive.

The LVDT is positioned across the opening of the caliper where it measures the opening and closing of the jaws. Both the axial and radial devices are designed so that self-weight is partly counteracted by buoyant uplift.

#### Key Features:

Inherently robust LVDT's as they have no physical contact across the sensing element:

Submersible low pressure version for use in water:

Vented high pressure version for use in non-conducting oil only:

Through bore configurations:

Radial sprung aluminium-bronze hinge for no backlash and low friction:

#### Benefits to the User:

Zero wear ensuring longer life and lower friction effects.

Can be used up to 3500kPa.

Can be used up to 200MPa.

Allows test to continue after the LVDT has passed its measurement range.

The transducers measure sample effects not those of the measuring calipers.

### Connecting LVDT's to a DC data acquisition system

The principal output of a Linear Variable Differential Transformer (LVDT) is an AC waveform. In addition, although an LVDT is an electrical transformer, it requires AC power of an amplitude and frequency quite different from ordinary power lines to operate. Supplying this excitation power for an LVDT is one of several functions of the GDS LVDT signal conditioning equipment, or 'GDS LVDT box', supplied as standard with the transducers from GDS. GDS supplies the required calibrated signal conditioning equipment for the LVDT's to output a +/-10V DC signal. This output level is perfectly suitable to all GDS, and most other manufacturer's data acquisition equipment. The LVDT box can be recalibrated by the user for different output levels below 10V if necessary.

## Why measure small strain?

Very small strains are typically associated with the soil response to dynamic loading. It is now well established that small strain behaviour also plays an important role in soil response to static loading. Simpson (1992), Burland (1989) and others showed that the strain level around engineering structures is in the range of small to moderate strains (up to 0.2%) emphasising the importance of evaluating the decay of stiffness with strain. The benchmark parameter of this characteristic stiffness-strain curve for any soil, which is not currently yielding is the very small strain shear modulus or  $G_{max}$ , which is sometimes also referred as  $G_0$ .

## Why measure locally on the specimen?

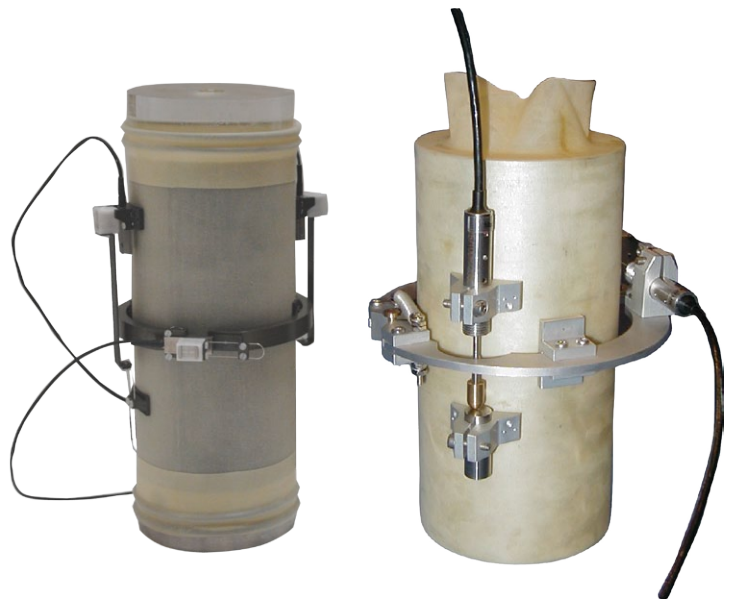
In the conventional triaxial test, surface friction arises between the unlubricated ends of the test specimen and the end platens of the test apparatus. The ends are therefore restrained laterally and hence vertically also. Accordingly, the test specimen deforms non-uniformly with a gradient of axial and radial deformation from zero at the ends to a maximum at the middle. It is widely believed that triaxial test specimens with a height to diameter ratio of 2 have end zones which are more or less restrained while the middle third is more or less unrestrained. Therefore, it is highly desirable that radial and axial deformations are measured locally in this region if realistic deformation moduli are to be found.

The measurement of axial deformation based on the relative movement between the top cap and the base pedestal is subject to bedding errors. These errors arise because of the difficulty in providing perfectly plane, parallel and smooth ends on the triaxial test specimen. The top cap can rest on surface asperities of the test specimen or make contact imperfectly, perhaps on one edge of the specimen. Owing to this "point" loading effect, rapid deformation will occur during the early stages of triaxial compression until the top cap is properly bedded down. Most triaxial tests (not using small strain) tend to give apparent soil stiffnesses far lower than those inferred from field behaviour (Jardine, Symes & Burland, 1984).

## How to choose between Hall Effects and LVDTs?

Whether people use LVDT's or Hall effects is a matter of personal preference.

- Hall Effects are very light and easy to handle, therefore generally considered easier to place on the sample itself. If easier to place and mounted well, arguably results will be better. If the sample is stiff this should be of no concern.
- With Hall Effects you can do small strain, however with LVDT's you have the possibility to 'very' small strain due to the higher accuracy.
- LVDT's are significantly more robust than Hall Effect chips, and due to this will almost certainly always last longer and be able to survive rough(er) treatment, however they are heavier, and only recommended on stiffer samples.



Hall Effect (left) & LVDT (right) Transducers



## Why Buy GDS?

### GDS have supplied equipment to over 84% of the world's top 50 Universities:

GDS have supplied equipment to over 84% of the world's top 50 Universities who specialise in Civil & Structural Engineering, according to the "QS World University Ranking 2019" report.

GDS also work with many commercial laboratories including BGC Canada, Fugro, GEO, Geolabs, Geoteko, Golder Associates, Inpijn Blokpoel, Klonn Crippen, MEG Consulting, Multiconsult, Statens Vegvesen, NGI, Ramboll, Russell Geotechnical Innovations Ltd, SA Geolabs, SGS, Wiertsema and Partners to name a few.

**TOP  
50**

### Would you recommend GDS equipment to your colleague, friend or associate?

**100% of our customers answered "YES"**

Results from our post-delivery survey asked customers for feedback on their delivery, installation (if applicable), supporting documentation, apparatus and overall satisfaction with GDS. The survey ran for two years.



### Made in the UK:

All GDS products are designed, manufactured and assembled in the UK at our offices in Hook. All products are quality assured before they are dispatched.

GDS are an ISO9001:2015 accredited company. The scope of this certificate applies to the approved quality administration systems relating to the "Manufacture of Laboratory and Field Testing Equipment".

**40 YEARS OF  
BRITISH  
INNOVATION** 

### Extended Warranties:

All GDS apparatus are covered by a 12 month manufacturers warranty. In addition to the standard warranty, GDS offer comprehensive extended warranties for 12, 24 and 36 months, for peace of mind against any repairs in the future. The extended warranties can be purchased at any time during the first 12 months of ownership.



### GDS Training & Installation:

All installations & training are carried out by qualified engineers. A GDS engineer is assigned to each order throughout the sales process. They will quality assure the apparatus prior to shipping, if installation has been purchased, install the apparatus on the customers site & provide the training.



### Technical Support:

GDS understand the need for ongoing after sales support, so much so that they have their own dedicated customer support centre. Alongside their support centre GDS use a variety of additional support methods including remote PC support, product helpsheets, video tutorials, email and telephone support.

