V1.0

VIBRATING WIRE SISTER BARS

INSTRUCTION MANUAL

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GEOSENSE

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1.0 INTRODUCTION

This manual is intended for all users of Vibrating Wire Sister Bars manufactured by Geosense and provides information on their installation, operation and maintenance.

It is VITAL that personnel responsible for the installation and use of these Strain Gauges, READS and UNDERSTANDS this manual, prior to working with the equipment.

1.1 General Description

Geosense VW Sister Bars Strain Gauges are environmentally sealed sensors that are used to register micro changes in length within concrete. Since strain is described as a change in length per unit length, these sensors detect small changes in their length and, by simple calculation, their output can then be converted to strain.

Sister Bars can be installed or included in many types of monitoring regime and can be linked to various types of readout equipment.

The primary uses for Sister Bars are the measurement of Load and Bending in concrete and composite structural members, with applications such as, but not limited to :-

- Bored, Cast In-situ, Pile Foundations
- Retaining Walls
- Floor Slabs
- Columns and Beams
- Mass concrete dams
- Strutting and Temporary Works
- Bridgeworks

Particular features of the Geosense VW Sister Bar Strain Gauges are:-

- Reliable long term performance.
- Rugged, suitable for demanding environments.
- High accuracy.
- Insensitive to long cable lengths.

Sister Bars are based upon the 'industry standard' Vibrating Wire technology. When electronically excited, the sensors produces an output signal in the form of an alternating current. The frequency of the alternating current is measured and can then be readily converted to a change in strain.

Frequency signals are particularly suitable for the demanding environment of civil engineering applications since the signals are capable of long transmission distances without degradation. They are also somewhat tolerant of damp wiring conditions and resistant to interference from external electrical noise (EMI).

Geosense VW Sister Bar Strain Gauges are supplied in various configurations to suit varying installation environments and techniques.

Geosense VW Sister Bar Strain Gauge

1.2 Theory of Operation

Strain Gauges consist of a tensioned steel wire anchored at both ends. The wire is enclosed in a steel tube which is connected at both ends to a length of reinforcement bar (rebar). An example of the Sister Bar Strain Gauge configuration is shown above.

Electromagnetic coils are located within the body, close to the axis of the wire. When a brief voltage excitation, or swept frequency excitation is applied to the coils, a magnetic field is created, causing the wire to oscillate at its' resonant frequency. The wire continues to oscillate for a short period through the 'field' of the permanent magnet, thus generating an alternating current (sinusoidal) output. The frequency of this current output is detected and processed by a vibrating wire readout unit, or by a data logger equipped with a vibrating wire interface, where it can be converted into 'Engineering' units of Strain.

Forces within the structural element onto, or into, which the Sister Bar is fixed, cause the length of the gauge to change. The change in length of the gauge changes the tension of the wire which results in a change in resonant frequency of oscillation of the wire. The change in the square of frequency of oscillation is directly proportional to the change in strain in the structural element. For further information see Section 5 - Data Handling.

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EU Declaration of Conformity

We Geosense Ltd at above address declare that the equipment detailed below, complies with the requirements of the following EU Directives: -

- Electromagnetic Compatibility Directive **2014/30/EU**
- Restriction on the use of certain Hazardous Substances **RoHS2 2011/65/EU**

Equipment description:	**Vibrating Wire Strain Gauges**
Make/Brand:	**Geosense**
Model Numbers:	**VWS-2000, VWS-2010, VWS-2020, VWS-2025, VWS-2026** **VWS-2100, VWS-2120, VWS-2125, VWS-4000**

Compliance has been assessed with reference to the following standard:

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

A technical file for this equipment is retained at the above address.

Tim Clegg

Director
22/07/2022

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UK Declaration of Conformity

We Geosense Ltd at above address declare that the equipment detailed below, complies with the requirements of the following UK regulations: -

- Electromagnetic Compatibility Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Equipment description:	**Vibrating Wire Strain Gauges**
Make/Brand:	**Geosense**
Model Numbers:	**VWS-2000, VWS-2010, VWS-2020, VWS-2025, VWS-2026 VWS-2100, VWS-2120, VWS-2125, VWS-4000**

Compliance has been assessed with reference to the following designated standard:

EN 61326-1:2021 Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

A technical file for this equipment is retained at the above address.

Tim Clegg

Director
22/07/2022

3.0 DELIVERY

This section should be read by all users of Vibrating Wire Sister Bar Strain Gauges manufactured by Geosense.

3.1 Packaging

VW Sister Bar Strain Gauges are packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. However, inappropriate handling techniques may cause damage to the packaging and the enclosed equipment. The packaging should be carefully inspected upon delivery and any damage MUST be reported to both the transportation company and Geosense.

3.2 Handling

Whilst they are a robust devices, VW Sister Bars are precision measuring devices. They and their associated equipment should always be handled with care during transportation, storage and installation.

Once the shipment has been checked (see below), it is recommended that the Sister Bars remain in their original packaging for storage and transportation.

Cable should be handled with care. Do not allow it to be damaged by sharp edges, rocks for example, and do not exert force on the cable as this may damage the internal conductors and render the instrument useless.

3.3 Inspection

It is vital to check all the equipment in the shipment as soon as possible after taking delivery and well before installation is to be carried out. Check that all the components that are detailed on the documents are included in the shipment. Check that the equipment has not been physically damaged.

Geosense Vibrating Wire Sister Bar Strain Gauges are each supplied with a unique calibration factor (sometimes called 'Gauge Factor'). Each delivery will include details of the calibration factors that apply to the equipment supplied.

The integrity of the Bars can be checked easily by connecting the exposed ends of their connecting wires to a suitable Vibrating Wire Readout.

Prior to carrying out this ‘Functional’ CHECK, ensure that the Bars have been stored in a reasonably stable temperature for at least 2 hours.

The displayed values of the VW reading and temperature, should be reasonably stable (+/- 3 full digits) for this check.

Where possible, select the audio function on the readout and listen to the ‘ring’ of the gauge. The ‘ring’ should be clear and un-distorted.

Typical readout display

3.4 Storage

All equipment should be stored in an environment that is protected from direct sunlight.

Though robust, the gauge tubes are very sensitive to even slight bending so great care must be taken to store them carefully.

It recommended that cables be stored in a dry environment to prevent moisture migrating along the cable in the unlikely event of prolonged submersion of exposed conductors.

Storage areas should be free from rodents as they have been known to damage connecting cables.

No other special requirements are needed for medium or long-term storage although temperature limits should be considered when storing or transporting associated components, such as readout equipment.

4.0 INSTALLATION

This section of the manual is intended for all users of Vibrating Wire Sister Bar Strain Gauges manufactured by Geosense and is intended to provide **guidance** with respect to their installation.

It must be remembered that no two installations will be the same and it is inevitable that some 'fine tuning' of the following procedures will be required to suit specific site conditions.

It is VITAL that personnel responsible for the installation and use of the Sister Bar Strain Gauges READS and UNDERSTANDS the manual, prior to working with the equipment.

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As stated before, it is vital to check all the equipment in the shipment soon after taking delivery and well before installation is to be carried out. Check that all components that are detailed on the shipping documents are included.

4.1 Preparation for Installation

Each gauge should be assigned a unique identifying code or mark (in addition to the factory serial number marks) to identify its position in a particular structure (remembering, obviously, that the gauges fitted with the longest cables are will for most distant installation). Ensure there will be enough cable to route it to the intended readout / monitoring location.

The elevation / location of the Sister Bar installations should be identified by the Engineer responsible for the interpretation of the data, or as detailed on contract drawing or in the specification. The instrument locations should be marked using paint or other appropriate technique. It is important to consider the protection of each Sister Bar and its cable when selecting a suitable location. It must be remembered that Bars must be protected from damage as they are sensitive measuring instruments.

The function of Sister Bars should be checked prior to installation as described in **Section 3.3**. Check each Bar using a readout with the audio function switched on. A clear 'ring' should be produced from the VW gauge.

Illustrations provided within this manual use only one different models of portable readout. In general, any Vibrating Wire readout device could be used to excite and interrogate the Vibrating Wire Sister Bar Strain Gauges manufactured by Geosense.

4.2 Sister Bar Gauges into a Reinforcement cage - VWS-4000 Series

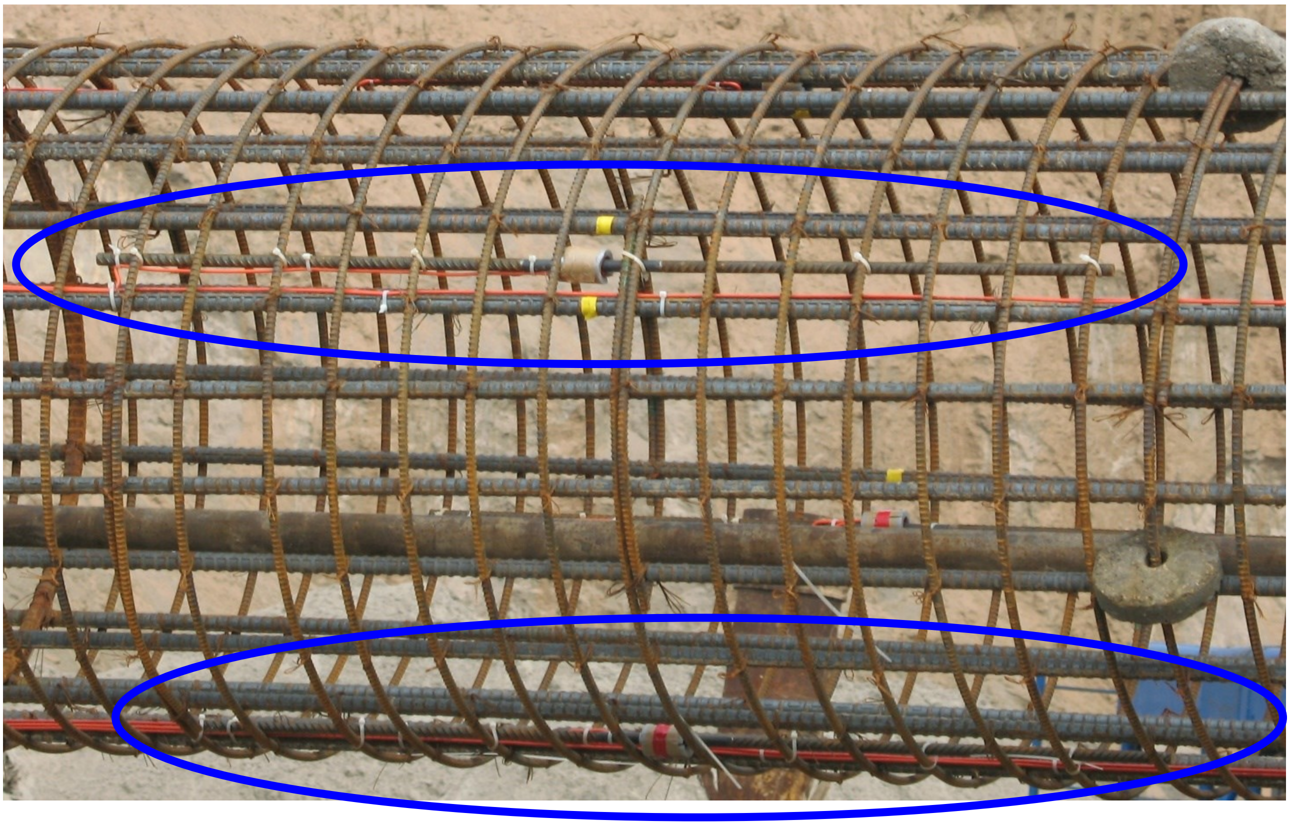
As its name implies, the ‘Sister Bar’ Strain Gauge is intended for inclusion in concrete ‘alongside’ other reinforcement bars.

Sister Bar Strain Gauges are available in various diameters and lengths but the installation principles are generally the same.

Sister Bars are normally fixed into a reinforcement cage so that they are parallel to the main reinforcement bars. However, they can be aligned in any direction, provided that precautions are taken not to damage the Sister Bars during any moving of the cage or when placing the concrete. Sister Bar Strain Gauges will measure the strain in the concrete ONLY in the direction along the axis of the Sister Bar.

DO NOT fix Sister Bars directly onto parallel reinforcement bars as this could bend the Sister Bar, thereby inducing bending stresses into it.

Where there is no existing support for a Sister Bar at its intended location within a reinforcement cage, it will be necessary to introduce additional bars onto which the instrument can be mounted. Generally, these support bars need to be 12 to 16mm in diameter and fixed into the reinforcement at roughly 90 degrees to the intended orientation of the Sister Bar. It is necessary to firmly fix the additional support bars so that the orientation of the Sister Bar is maintained during any cage movement and concreting. The Sister Bar must be fixed at 4 or more points along it length, as shown below.



A pile cage with an array of 4 Sister Bars installed between the Main Bars

In this installation, Nylon cable ties have been used to fix the Sister Bars to the reinforcement cage. Annealed iron stainless wire can also be used for fixing the Sister Bars.

4.2 Sister Bar Gauges into a Reinforcement cage - VWS-4000 Series contd...

Sister Bars, ready for installation…..

It is advisable to form a small loop of cable close to the gauge, to help reduce the risk of damage to the gauges if the cable should be come snagged or pulled.

In some installations the installing engineer chooses to isolate the ‘Strain Gauge Coil Housing from the concrete using a foam tube, as can be seen in this photograph. This is not essential and will not affect the overall performance of the gauge.

Sister Bar Strain Gauges mounted between the main bars in a pile cage and the cables routed on the side of the main bars, to provide protection.

4.2 Sister Bar Gauges into a Reinforcement cage - VWS-4000 Series contd...

Routing of the instrument cables must be carried out so that they are not at risk of damage during the preparatory works or during concreting. For pile cage installations, the routing considerations are the same as those for the embedded strain gauges (Section 4.2.1).

In other installations, the cable protection principles are similar.

Sister Bars are NOT intended to be used as Re-Bar Stain Meters. They are NOT intended to be load carrying and are NOT intended to REPLACE the steel in the designed reinforcement

5.0 DATA HANDLING

The function of the instrument is to provide useful and reliable data. Accurate recording and handling of the data is essential if it is to be of any value.

5.1 Monitoring the Sister Bar Strain Gauge Readings

Where a Sister Bar Strain Gauge is installed in a zone where its temperature is likely to fluctuate significantly, The measured Strain changes WILL be affected by the thermal changes in the concrete and the steel. Consequently, records of both strain and temperature changes should be used to assess the effects temperature on the strain data.

All Geosense VW Sister Bar Strain Gauges contain temperature sensors.

5.1.1 Portable Readouts

Geosense offer a range of readout and data logging options. Specific operation manuals are supplied with each readout device.

Below is a brief, step-by-step procedure for use with the **Geosense VWR-1** portable readout.

1. Connect the cable from the sensor to the readout following the wiring colour code. Conductor colours may vary depending upon the extension cable used. Commonly these are:

RED	=	VW +
BLACK	=	VW -
GREEN	=	Temp
WHITE	=	Temp

2. Press the 'On/Off' button to switch the unit on. Press it again to acquire a reading from the connected instrument.

3. The readout displays the Vibrating Wire readings in both 'Frequency' (in Hz) and Linear 'B' Digits (in $Hz^2/1000$). Temperature reading in both resistance (Ohms) and degrees C.

   For more details see the readout manual.

4. Press and hold down the On/Off' button to switch the unit off.

Whilst it is not critical that the polarity be observed for most VW instruments, a stronger signal may be obtained if the correct polarity is adopted. Since the temperature sensor is a Thermistor, its connection polarity is not important.

5.1.2 Data Loggers

A number of data loggers are available to automatically excite, interrogate and record the reading from Vibrating Wire instruments. These include (but not limited to) the GeoLogger, GeoLogger Linx and equipment manufactured by Campbell Scientific Ltd.

5.2 Data Reduction Overview

The tension of a Vibrating Wire sensor wire can be measured by detecting the frequency at which it naturally vibrates.

The wire is 'excited' electronically the frequency at which it vibrates can be measured and the following are descriptions of the units commonly used by the instrumentation industry.

Frequency Units (Hz). The units used to express frequency are Hertz (Hz) or Kilo-Hertz (kHz).

The disadvantage of these units is that there is no 'linear' conversion from 'change in Hertz' to 'change in wire tension'.

Linear Digits (B). In order to overcome the problem of a linear conversion described above, the frequency value can be squared, thereby rendering it linear, but quite large. To reduce its size, it is often divided by 1000 (or multiplied by 10^{-3}). The expression $Hz^2/1000$ (or $Hz^2 \times 10^{-3}$) is the most commonly adopted as a 'linear' digital output.

Period Units (P). Some older readout devices utilise the 'counter' function available in many common integrated circuits.

Period Units represent the time taken for the wire to vibrate over one full oscillation, expressed in seconds. Due to the very small size of the number generated most equipment manufacturers display these units multiplied by either 1000 (10^3) or 10000000 (10^7).

The relationship between Period units and Frequency units is expressed as

$$\text{Period} = 1 \div \text{Frequency}$$

Period units are convenient to measure but do not have a linear relationship to the 'change in wire tension'. They must first be converted to Frequency then converted as above.

Calibration Factor. Each instrument is supplied with a Calibration Sheet which included a Calibration Factor (sometimes called 'Gauge Factor' or 'Constant'), to enable conversion from the raw data (in the Linear units described above) into engineering units such as micro-strain.

All Geosense Sister Bar Strain Gauges are individually calibrated so have unique calibration factors.

Direct readings from Vibrating Wire Strain Gauges are typically in a form that is a function of frequency (as above) rather than in units of strain.

(Continued on page 15)

5.2 Data Reduction Overview … cont.

If a readout display is in ‘Period’ units (e.g. 0.03612 or 3612 depending upon the readout used) a calculation must first be performed to convert the reading from ‘Period’ units to ‘Linear Digits’ ($Hz^2/1000$) units.

Two examples of this can be seen below. The first (1) where readout includes a decimal point and displays the Period in ***Seconds***$^{-2}$ and the second (2) where the readout displays the Period in **Seconds**$^{-7}$

(1) Linear $Hz^2/1000$ $= (\text{Reading} \times 10^{-2})^2 / 1000$
$= (1 / \mathbf{0.03612} \times 10^{-2})^2 / 1000$
$= 7664.8$

(2) Linear $Hz^2/1000$ $= (1 / \mathbf{3612} \times 10^{-7})^2 / 1000$
$= 7664.8$

If the readout displays ‘Frequency’ values, (e.g. 2768.5 Hz) only a simple calculation is required to convert the reading to Linear Digits.

Linear Digits ($Hz^2/1000$) $= (\text{Reading})^2 / 1000$
$= (2768.5)^2 / 1000$
$= 7664.6$

NB. Certain data loggers store their Vibrating Wire data in Linear Digits but divided by a further 1000. Obviously these data would have to be multiplied by another 1000 to maintain the standard data format for the conversion to engineering units.

5.3 Strain Calculation

To simply convert the change in Linear Digits to Strain, the following equation applies:

$$\varepsilon \text{apparent} = (R_1 - R_0) \times C$$

Equation 1 - Apparent Strain

Where :-
R_0 is the initial reading in digits, usually obtained at installation or at the commencement of a test.
R_1 is the current reading in digits.
C is the calibration factor from the supplied calibration report.

For example: Assuming an initial reading (R_0) of 7854 digits, a current reading (R_1) of 7528, and a calibration factor (C) of 0.343 micro-strain per digit; the strain calculation would be as follows:

εapparent = (7528 - 7854) × 0.343 = - 112 **$\mu\varepsilon$** (compression)

Apparent strain = (7528 – 7854) x 0.343 = **– 112 µstrain (compression)**

5.4 Temperature Considerations

It is assumed that, with Sister Bars embedded in concrete, the strain in the Sister Bar is equal to the strain in the concrete. However, when the temperature changes, the concrete expands and contracts at a rate slightly less than the rate of the steel of the vibrating wire sensor. It should be noted that the Sister Bar temperature readings is not necessarily representative of the whole concrete element.

The rate of temperature change and the distribution of the thermal gradients also play a major part in influencing the actual strain in the structural element. Consequently, in order to apply a correction for the effects of temperature changes, it is necessary to first establish the effects of the changes on the Sister Bars and the medium into which it is installed.

Approximate coefficients of this expansion / contraction of the materials are shown below.

Steel (K-steel):	12.2 ppm/°C	6.7 ppm/°F
Concrete (K-concrete)*:	≈10 ppm/°C	≈5.5 ppm/°F
Difference (K):	2.2 ppm/°C	1.2 ppm/°F

* may vary depending upon concrete specification

Because of the difference in these two coefficients, a correction is required to the ‘apparent’ strain, equal to the difference of the two coefficients. The equation for this correction is as follows:

$$\varepsilon_{load\ related} = ((R_1 - R_0) \times C) + ((T_1 - T_0) \times K)$$

Equation 2 - Load Related Strain

Where :-

T_0 is the initial temperature recorded at the time of installation.
T_1 is the current temperature.
K is the thermal coefficient from above

The strain calculated here is due to load changes only. 7528 - 7854

Using the same theoretical example from earlier in this section, where R_0 = 7854 Digits and R_1 = 7528 Digits with the addition of a temperature change, T_0 = 20 °C and T_1 = 60 °C (during the concrete curing), the strain corrected for temperature (i.e. due to load changes only) can be calculated as follows:

$$\varepsilon_{load\ related} = (7528 - 7854)\ 0.343 + ((60 - 20)*(12.2_{steel} - 10_{concrete})) = -24\ \mu\text{strain}$$ (compression)

Load related strain = (7528 – 7854) x 0.343 + (60 – 20) x (12.2 – 10) = **– 24 µstrain (compression)**

Note that the actual strain experienced by the concrete, **the physical change**, is given by the formula:

$$\varepsilon_{actual} = ((R_1 - R_0) \times C) + ((T_1 - T_0) \times K_{steel})$$

Equation 3 - Actual Strain

Actual strain = (7528 – 7854) x 0.343 + ((60 - 20) x (12.2)) = **+376 µstrain (tension)**

To summarise the results …

Apparent strain = (7528 – 7854) x 0.343 = **– 112 µstrain (compression)**

Load related strain = (7528 – 7854) x 0.343 + (60 – 20) x (12.2 – 10) = **– 24 µstrain (compression)**

Actual strain = (7528 – 7854) x 0.343 + ((60 - 20) x (12.2)) = **+376 µstrain (tension)**

From the above example, it can be seen that while the concrete was actually expanding by 376 micro-strain due to the temperature increase, the apparent strain was 112 micro-strain in compression, and the actual change of strain due to increased stress in the concrete (due to load) was only 24 micro strain compression.

Apparent strain is from the readings that are from the sensor.

Load related strain removes any effect on the Strain Gauge due to differences in steel and concrete and, in effect, is showing the change in strain of the concrete shown by the gauge.

(If the result from **Load related strain** was 0, it would be assumed that the concrete had expanded fully (unrestricted) by the thermal expansion factor multiplied by the change in temperature. The strain (physical change in length) would still be experienced within the structure but the gauge would not register it.

Actual strain is the amount of strain (physical length change) the structure would be expected to experience due to the temperature expansion of concrete.

To help understand the in-situ effects of thermal changes, a useful exercise to carry out on site is to observe the installed gauge readings, together with both ambient and gauge temperatures, when no other factors are changing. This should be carried out prior to any loading or other structural changes / works being carried out.

An alternative, is to use a 'No Stress Sister Bar' installed close to the monitoring Sister Bars. This will enable an assessment of temperature affects on the sensor output itself, in the working environment for a particular location. For details of 'No Stress Sister Bar', please contact Geosense.

5.5 Other Environmental Factors

Since the purpose of the instrument installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor factors may have a real influence on the behaviour of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal levels, traffic, temperature and barometric changes, weather conditions, changes in personnel, nearby construction activities, excavation and fill level sequences, seasonal changes, etc.

5.6 Shrinkage Effects

A well know property of concrete is its likely to shrink as the water content diminishes and to swell as it absorbs water. This shrinkage and swelling can give rise to large strain changes that are not related to load or stress. The magnitude of these strains can be several hundred micro-strains. It is difficult to compensate for these unwanted strains. An attempt may be made to keep the concrete under a constant condition of water content, but this is frequently impossible on concrete structures exposed to varying weather conditions. The shrinkage and/or swelling effect may be measured by casting a strain meter inside a concrete block that remains unloaded, yet still exposed to the same moisture conditions as the active gauges. Strains measured on this gauge may be used as a correction factor.

5.7 Converting Strains to Loads

The load in any structural element to which the strain gauge is attached is given by the formula:

$L = E \mu A$
Equation 5 - Strain to Load Formula

Where;
L is the load.
E is the elastic modulus of the structural element in the appropriate units.
μ is the strain in micro-strain.
A is the cross-sectional area in the appropriate units.

When installing Sister Bars in concrete piles it is standard practice to install them in pairs on either side of the neutral axis. This allows any strains imposed by bending to be corrected by taking the average strain of the two gauges. It is also standard practice to install a pair of strain meters close to the top of the pile. The measured strain of these two gauges is used to calculate the modulus of the concrete.

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SISTER BAR CALIBRATION

Serial No:	**411341**	**Model:**	**VWS-4000**	**Cal Date:**	**02/10/2023**
Works ID:	**825**	**Batch:**	**96**	**Diameter:**	**16 mm**
Shipment Reading:		**8395.8**	**Cable Length (m):**		**40**

Applied Load	**Readings [digit]**			**Indicated Load**	**Error % FSO**
kN	Rdg 1	Rdg 2	Avg	kN	Linear
0.00	8399.9	8409.6	8404.7		
5.00	8867.3	8872.4	8869.8	5.02	0.09
10.00	9345.7	9346.2	9346.0	9.99	-0.03
15.00	9822.1	9823.2	9822.7	14.97	-0.13
20.00	10303.7	10304.8	10304.3	19.99	-0.02
25.00	10785.4	10786.6	10786.0	25.02	0.09

CALIBRATION FACTORS

	Microstrain per digit
Linear Factor (S)	3.26867E-1

Linear Calculation [Microstrain] = S * (Current Reading - Site Zero Reading)

THE EQUIPMENT USED IN THE CALIBRATION OF THE PRODUCT DETAILED ABOVE IS TRACEABLE TO NATIONAL/INTERNATIONAL STANDARDS

Digits = $Hz^2 \times 10^{-3}$

CALIBRATED TO UKAS TRACEABLE STANDARD - ISO 9001:2015
THIS IS AN ELECTRONIC CERTIFICATE AND IS VALID WITHOUT A SIGNATURE

6.0 MAINTENANCE

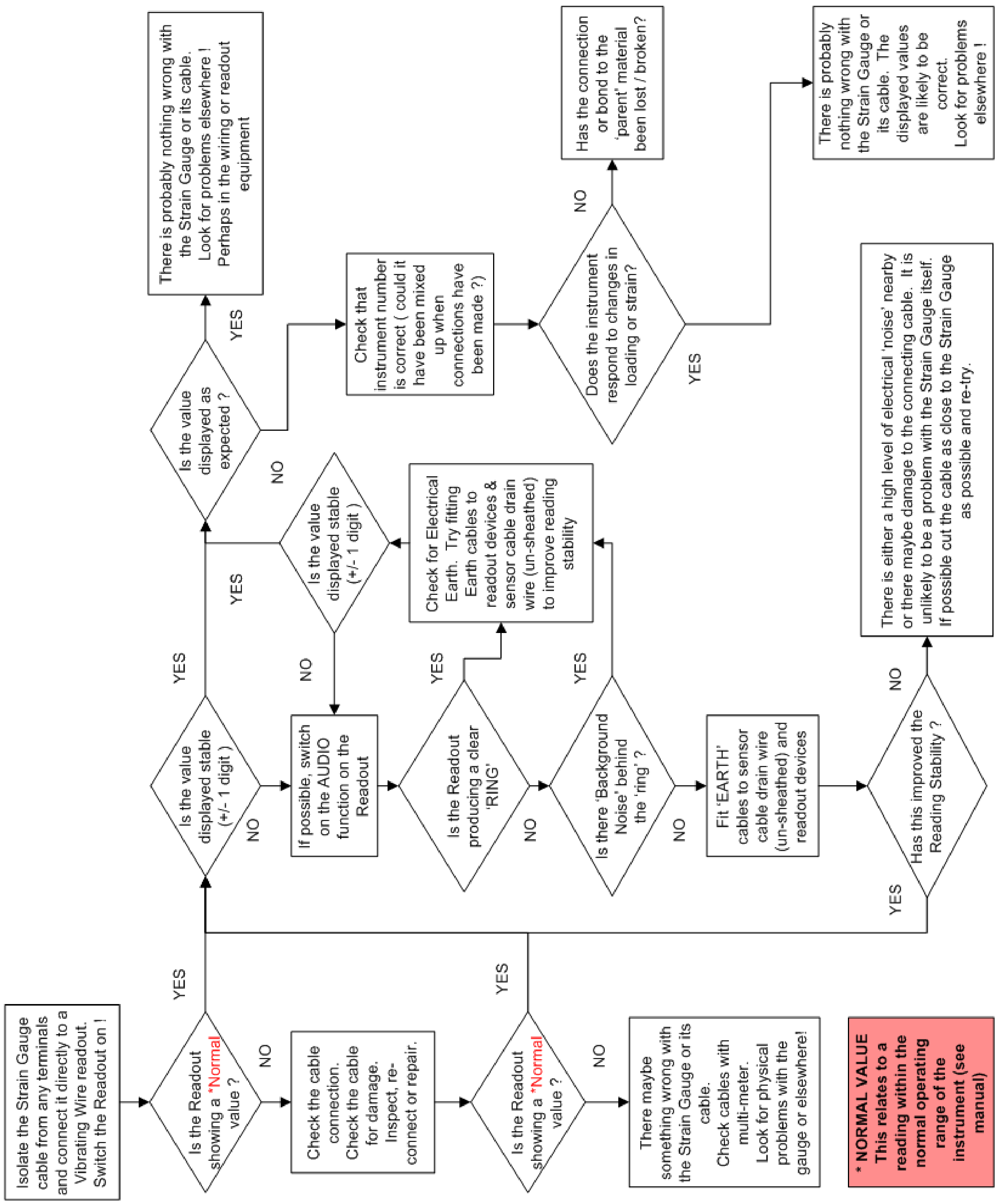
The Vibrating Wire Sister Bar is a maintenance free device for most applications. This is because it is intended for sub-surface installation and would normally be irretrievably sealed into structural materials.

Maintenance of wiring connections between the Strain Gauge and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning contacts to prevent the build up of corrosion

7.0 TROUBLESHOOTING

It is generally accepted that when a Vibrating Wire instrument is producing a stable reading on a suitable readout, the value will be correct. Only on very rare occasions will this be untrue.

In almost all cases, a fluctuating reading is a sign of a faulty signal from the sensor. The fault could be in either the sensor, the connecting cable, any switch boxes or the readout. The best way to fault find an instrument is to isolate it from all other instruments and connections. Where possible begin fault finding from the sensor itself.



8.0 SPECIFICATION

Model Number	**VWS-4000**	**VWS-4001**
Type	Sister Bar	Rebar
Overall Length (mm)	915*	915*
Re-bar diameter	12mm / 16mm*	12mm / 16mm*
Resolution (με)	0.4	0.4
Strain range (με)	2600	2600
Frequency range (Hz)	1500 - 3500	1500 - 3500
* other diameters and lengths available upon request		

Resolution	1 μЄ (Readout Dependent)
Accuracy	Better than 0.2% Full Scale
Thermal Effect	Less than 0.02% Full Scale per °C **
Operating Range	-20 to + 95 °C
Temperature Sensor (optional)	Thermistor (3kΩ @ 25°C)
Over Range Capacity	Range + 20%
Excitation	Pluck or Swept Frequency

9.0 SPARE PARTS

As a Vibrating Wire Embedment Strain Gauge is a sealed unit, it is neither serviceable nor does it contain any replaceable parts.

Civil engineering sites are hazardous environments and instrument cables can be easily damaged, if they are not adequately protected. Geosense can therefore provide the following parts that my be required to effect repairs to instrument cables:

- PU coated 4 Core cable with foil shield and copper drain.
- PVC coated, armoured, 4 Core cable suitable for direct burial.
- Epoxy jointing kit for forming a waterproof cable joint.

Please contact Geosense for price and availability of the above components.

10.0 RETURN OF GOODS

10.1 Returns procedure

If goods are to be returned for either service/repair or warranty, please fill in the information via the website https://www.geosense.co.uk/returns/ where a **Returns Authorisation Number** together with **a Returns Form** will be automatically generated and sent to you via email.

The **Returns Form** should be sent together with the returned goods

10.1.1 Chargeable Service or Repairs

Inspection & estimate
It is the policy of Geosense that an estimate is provided to the customer prior to any repair being carried out. A set charge for inspecting the equipment and providing an estimate is also chargeable.

10.1.2 Warranty Claim

(See Limited Warranty Conditions)
This covers defects which arise as a result of a failure in design or manufacturing. It is a condition of the warranty that the Vibrating Wire Strain Gauge must be installed and used in accordance with the manufacturer’s instructions and has not been subject to misuse.

In order to make a warranty claim tick the warranty claim box under **REASON FOR RETURN** on the website and return the goods as above. You will then be contacted and informed whether your warranty claim is valid.

10.2 Packaging and Carriage

All used goods shipped to the factory **must** be sealed inside a clean plastic bag and packed in a suitable carton. If the original packaging is not available, Geosense should be contacted for advice. Geosense will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

10.3 Transport & Storage

All goods should be adequately packaged to prevent damage in transit or intermediate storage.

11.0 LIMITED WARRANTY

The manufacturer, **Geosense Limited**, warrants the **Vibrating Wire Strain Gauge** manufactured by it, under normal use and service, to be free from defects in material and workmanship under the following terms and conditions:-

Sufficient site data has been provided to **Geosense** by the purchaser as regards the nature of the installation environment to allow **Geosense** to check material compatibility of the **VIBRATING WIRE STRAIN GAUGE** and other component parts.

In the absence of any site data being provided by the purchaser standard construction materials will be supplied. All costs for subsequent modifications will be borne by the purchaser.

The **Vibrating Wire Strain Gauge** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 1 year from the date of shipment from the manufacturer to the purchaser.

The warranty is limited to replacement of part or parts which, are determined to be defective upon inspection at the factory. Shipment of defective part or parts to the factory shall be at the expense of the Purchaser. Return shipment of repaired/replaced part or parts covered by this warranty shall be at the expense of the Manufacturer.

Unauthorised alteration and/or repair by anyone which, causes failure of the unit or associated components will void this **LIMITED WARRANTY** in its entirety.

The Purchaser warrants through the purchase of the Vibrating Wire Strain Gauge equipment that he is familiar with the equipment and its proper use. In no event shall the manufacturer be liable for any injury, loss or damage, direct or consequential, special, incidental, indirect or punitive, arising out of the use of or inability to use the equipment sold to the Purchaser by the Manufacturer.

The Purchaser assumes all risks and liability whatsoever in connection with the Strain Gauge equipment from the time of delivery to Purchaser.

APPENDIX - Thermistor Linearization

USING STEINHART & HART LOG

Thermistor Type: 3K @25°C

Resistance/ temperature equation:-

$$T = (1 / (A + B\,(LnR) + C(LnR)^{3})) - 273.2$$

Where:-

T = Temperature in degrees Centigrade
LnR= Natural log of Thermistor resistance.
$A = 1.4051 * 10^{-3}$
$B = 2.369 * 10^{-4}$
$C = 1.019 * 10^{-7}$

Resistance versus temperature table

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149

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