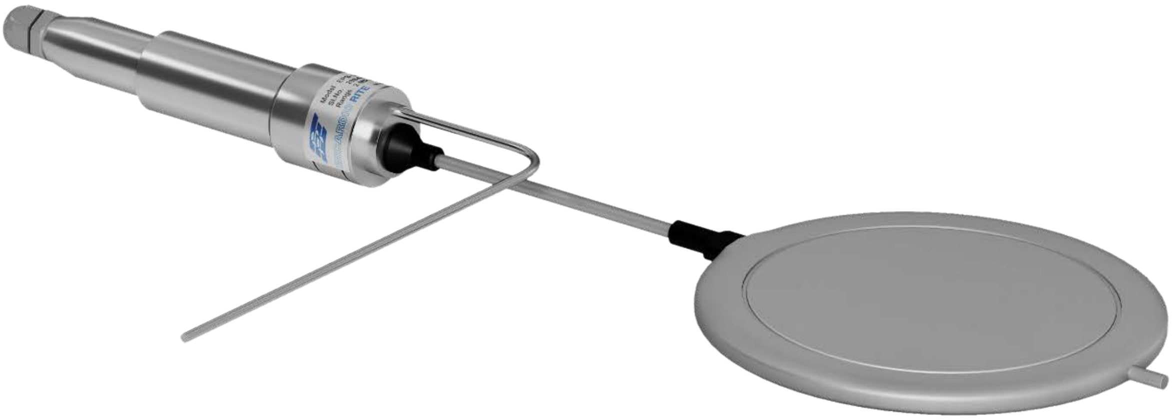
ENCARDIO RITE

ONE STOP MONITORING SOLUTIONS | HYDROLOGY | GEOTECHNICAL | STRUCTURAL | GEODETIC
Over 50 years of excellence through ingenuity

USERS' MANUAL

VIBRATING WIRE CONCRETE PRESSURE CELL FOR MEASUREMENT OF TOTAL PRESSURE IN CONCRETE

MODEL EPS-30/36V-C



Doc # WI 6002.29 R03 | May 2004

ENCARDIO-RITE ELECTRONICS PVT. LTD.
A-7, Industrial Estate, Talkatora Road Lucknow, UP - 226011, India | P: +91 522 2661039-42 | Email: geotech@encardio.com | www.encardio.com
International: UAE | Qatar | Bahrain | Bhutan | Morocco | Europe | USA | UK
India: Lucknow | Delhi | Kolkata | Mumbai | Chennai | Bangalore | Hyderabad | J&K

Contents

1 INTRODUCTION

The theology of soil/rock formations is a complicated function of soil/rock type, stress history, shear and normal stress levels, boundary and drainage conditions and many other environmental effects. Accurate assessment of stress in foundation soil/rock formations and changes in it caused by construction and loading is important for good engineering design. In instrumentation schemes for geotechnical or geo-structural study associated with large civil engineering structures like tall buildings, dams, underground tunnels etc., measurement of stress plays a very important part.

Encardio-rite manufactures a range of instruments for measurement of stress, including sensors, readout unit and data logger.

Study of stress fall into two basic categories:

- Measurement of total stress at a point within a soil mass/foundation rock/concrete structure.
- Measurement of contact stress against the face of a structural element.

The development of vibrating wire stress cell introduced a reliable and fast method of taking stress readings electrically. The cable is carried from the stress cell to the read out unit or data logger and is protected against any possible damage during construction to give all around reliable data.

Encardio-rite vibrating wire concrete pressure cell (or stress cell) is the electrical sensor of choice as frequency output of the vibrating wire sensor is almost immune to external noise, it is able to tolerate wet wiring conditions common in geotechnical applications and is capable of transmission of signals to long distances.

It has applications in the measurement of stress in soil, concrete mass or foundation rock including:

- Total stress on and within liners of underground excavations as input to improve design and construction practices.
- Magnitude, orientation and distribution of principal stresses within embankments and dams as input to improve design and construction practices.
- Total stress for studying soil/structure interaction behaviour.

For details of vibrating wire stress cell manufactured by Encardio-rite, refer to data sheet 1090-97w.

1.1 Concrete pressure cell

The concrete pressure cell is designed to measure total pressure in concrete. Proper evaluation of total pressure may help in:

- Verifying design assumptions that will promote safer and more economical design and construction.
- Monitoring for safety and warning of pressure in excess of those the structure is designed to withstand.

The Encardio-rite concrete pressure cell basically consists of a flexible circular flat capsule, constructed from two stainless steel discs welded around the periphery and connected to a specially designed Encardio-rite pressure transducer by a stainless steel tube. A pinch tube is provided to ensure positive contact between the concrete and the circular flat discs. The whole system is fluid filled.

The vibrating wire pressure transducer incorporates the latest vibrating wire technology to provide remote and digital readout. Total pressure cell manufactured by Encardio-rite, designated with a suffix 'C' is used for measuring stress in concrete.

1.2 Specifications

Type	Vibrating wire
Model	EPS-30/31/32/33/34/35/36V-C
Range (kg/cm^2)	5, 10, 20, 35, 50, 100, specify
Over range limit	150 % of range upto 200 kg/cm^2; 120 % of range for > 200 kg/cm^2
Enclosure	Stainless steel
Thermistor	Provided for temperature measurement
Read out	EDI-54V

1.3 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

1.4 How to use this manual

This users' manual is intended to provide sufficient information for making optimum use of vibrating wire stress cell in your application. This users manual covers description of the stress cell with its connected accessories, the installation procedure and maintenance of the sensor, method of taking observations and recording data from the sensor.

NOTE: The installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However the best of instruction manuals cannot provide for each and every condition in the field that may affect the performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

To make this manual more useful, we invite your valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors that you may find while going through this manual.

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For an insight into the concrete pressure cell: See § 2 'Vibrating wire concrete pressure cell'.

For a typical test certificate on concrete pressure cell: See § 2.7 'Sample test certificate'.

For complete operating procedure of Vibrating Wire Readout Unit EDI-54V: See:'Doc. # WI 6002.112'

For essential tools and accessories: See § 3 'Tools and accessories required for installation'.

For installation of concrete pressure cell: See § 4 'Installation procedure'.

For temperature measurement by thermistor: See § 5 'Temperature measurement'.

For trouble shooting: See § 6.3 'Trouble shooting'.

2 VIBRATING WIRE CONCRETE PRESSURE CELL

2.1 Introduction

Encardio-rite concrete pressure cell is also called total pressure cell or total stress cell. It measures stress when embedded in concrete structures. Cell responds not only to concrete pressure but also to pore water pressure and therefore is termed as total pressure or total stress. A simultaneous measurement of pore water pressure (ρ), using a piezometer, is necessary to separate the effective stress (σ) from the total stress (σ_t) as defined by Terzaghi's principle of effective stress:

$$\sigma_t = \sigma + \rho$$

NOTE: The concrete pressure cell measures total stress. In case effective stress is to be measured a pore pressure meter must be installed close by.

2.2 General description

2.2.1 Flat stress capsule

The flat pressure capsule is 200 mm ϕ x 7 mm thick. It is constructed from two stainless steel plates electron beam welded together around the periphery to form a diaphragm so as to leave a narrow space between the plates. The flat pressure capsule is connected to a standard Encardio-rite vibrating wire pressure sensor through a 6 mm o.d. stainless steel tube welded on one side to pressure capsule and on other side to pressure transducer. Enclosed space is completely filled with de-aired fluid. De-airing materially improves the fluid stiffness and the performance of the cell. The concrete pressure cell uses an all welded construction such that space confining hydraulic fluid is entirely metal, not requiring 'O' rings that tend to trap air and reduce cell stiffness.

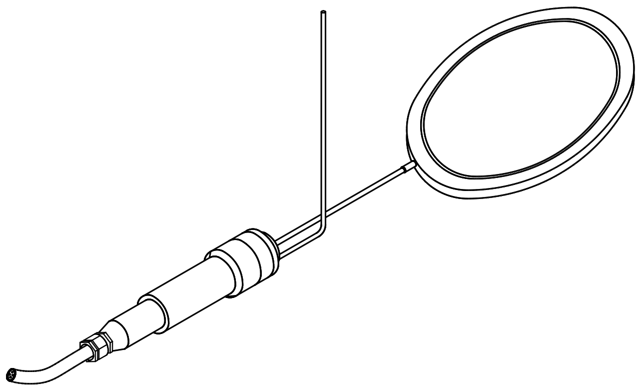


Figure 2.1

2.2.2 Pressure sensor with stainless steel body

The pressure sensor constitutes of a vibrating wire and coil magnet assembly enclosed in a stainless steel body which is electron beam welded to the diaphragm. This results in a vacuum of 1/1000 Torr inside the sensor making it completely immune to the effect of any ingress of water. As the pressure sensor is of stainless steel construction, it is not affected by normal chemical corrosion at locations in which it is used. The pressure sensor normally employed is the Encardio-rite pore pressure meter model EPP-30/36V that is available in several different pressure ranges (3, 5, 10, 20, 35, 50 & 100 kg/cm^2). Sensors upto capacity of 350 kg/cm^2 are also available.

A tripolar plasma surge arrestor inside the transducer housing protects the vibrating wire pluck and read coils from electrical transients such as may be induced by direct or indirect lightning strikes.

A thermistor is provided to monitor temperature.

2.2.3 Pinch tube

One end of 600 mm long pinch tube filled with hydraulic fluid is welded to pressure sensor. Other end is capped by welding. During concrete lining, temperature very often rises, causing capsule to expand in still green concrete. On cooling, capsule contracts, which if allowed to remain as such, would prevent transmission of pressure from concrete to cell. Purpose of pinch tube is to inflate capsule after concrete around it fully cures and cools off to ambient temperature. A crimping tool is used to squeeze hydraulic fluid in pinch tube. The fluid is forced out of tube into capsule, which expands until the gap is eliminated.

2.2.4 Cable connection

Leads from coil magnet are terminated on a glass to metal seal that is integrally electron beam welded to stainless steel body of pressure sensor. The two pins marked red and black are connected to coil magnet. The other two pins are connected to a thermistor for measurement of temperature. Cable joint housing and cable gland is provided for cable connection. Cable is attached to sensor in a sealed, water-resistant manner. For concrete pressure cell located inside a concrete block, cable may be armoured and provided with strain relief at cell to reduce likelihood of pull-out. For cable jointing, refer to Users Manual 6002.11.

2.3 Concrete pressure cell construction

2.3.1 Dimensional details of round cell manufactured by Encardio-rite is standardized and given below.

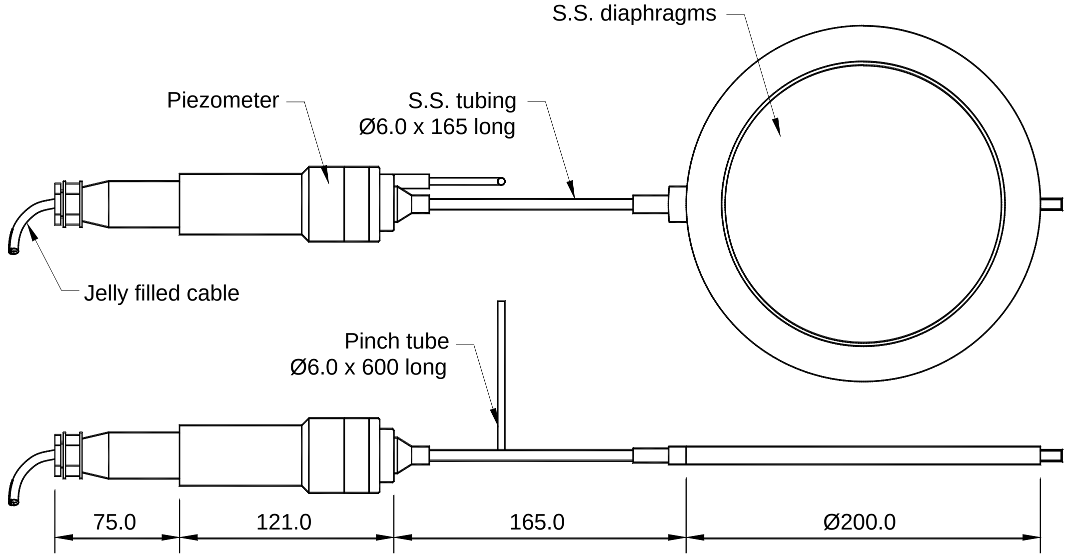


Figure 2.2 - concrete pressure cell with circular diaphragm

2.3.2 Concrete pressure cells are also available with rectangular diaphragm in sizes of 100 mm x 200 mm, 150 mm x 250 mm and 200 x 300 mm. Standard thickness is 7 mm giving an aspect ratio greater than 20. Dimensional details of rectangular concrete pressure cell are as follows:

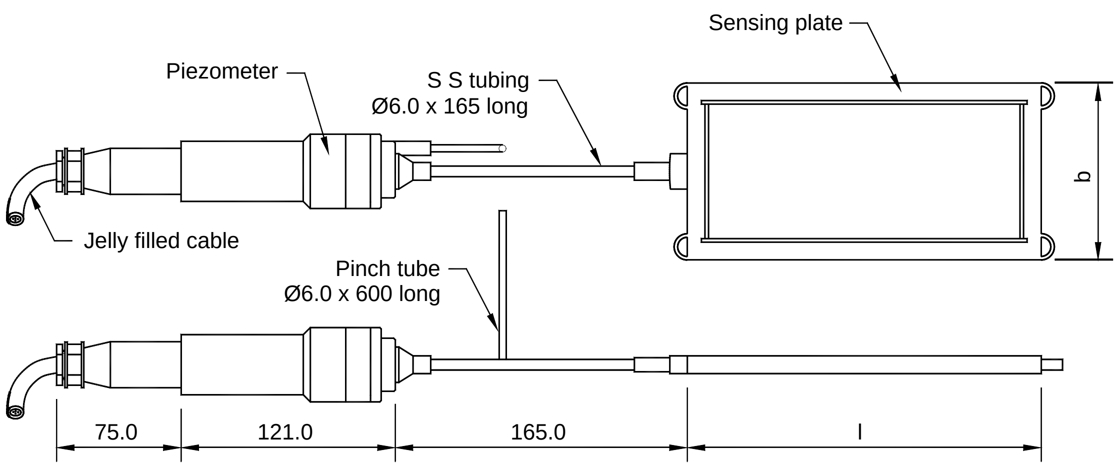


Figure 2.3 - concrete pressure cell with rectangular diaphragm

2.4 Pressure sensor operating principle

Pressure sensor of a vibrating wire stress cell consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and the other end fixed to a circular diaphragm. The diaphragm deflects in some proportion to applied pressure. Any change in pressure, deflects diaphragm proportionally affecting tension in stretched wire and in turns frequency of vibration The stress is proportional to the square of the frequency and the read out unit is able to display this directly in engineering units.

The wire is plucked by a coil magnet. Proportionate to the tension in wire, it resonates at a frequency 'f'', which can be determined as follows:

$$\mathbf{f = [\sigma g/\rho]^{1/2}/2l \ \ Hz}$$

where, σ = tension of wire in kg/cm^2
g = 980 cm/sec^2
ρ = density of wire in kg/cm^3
l = length of wire in cm

The length of the wire in the stress cell being 5.5 cm, the formula can be reduced to:

$$\mathbf{f = 32\ [\sigma]^{1/2} \ \ Hz}$$

The resonant frequency with which the wire vibrates, induces an alternating current in the coil magnet. This is read by the read out unit.

2.5 On interpreting data

The hydraulic type stress cell described above is a standard internationally used design and is manufactured by most of the reputed manufacturers. Depending upon the application and how and where it is used, it may generally give a reading upto 10 % different from the actual. Even though the stress cell is embedded in concrete, to understand the reason for this difference in reading from the actual, the following explanation using soil as an example is given:

2.5.1 Two flat plates are welded together at the periphery and are separated by a small gap filled with hydraulic fluid. The concrete pressure squeezes the two plates together building up a pressure on the fluid. The plates being thin relative to their lateral extent, are quite flexible. However, please note that there is some supporting effect of the welded periphery at center of the plate that may affect the reading.

2.5.2 Introduction of a flat stress cell into a mass alters stress field dependent on relative stiffness of cell with respect to surrounding material and also with respect to aspect ratio of cell, that is ratio of width of the cell to its thickness. A thick cell will alter stress more than a thin cell. Therefore, a thin stiff cell is best and studies have shown an aspect ratio of at least 20 to 1 to be desirable.

2.5.3 Ideally, the cell should be as stiff (compressible) as the material in which it is embedded. In practice, this is difficult. This is explained by the following examples in which the surrounding material could be soil or rockfill.

2.5.4 If the cell is stiffer (less compressible) than the material in which it is embedded (like soil) then it will over-register the pressure because a zone of material immediately around the cell is "sheltered" by the cell and does not experience the full pressure.

2.3.3 There is a stress concentration (figure 2.4) at the rigid rim but in the center of the cell the stress is only slightly higher than the mean stress, that is, only slightly higher than the normal stress had the pressure cell not been there.

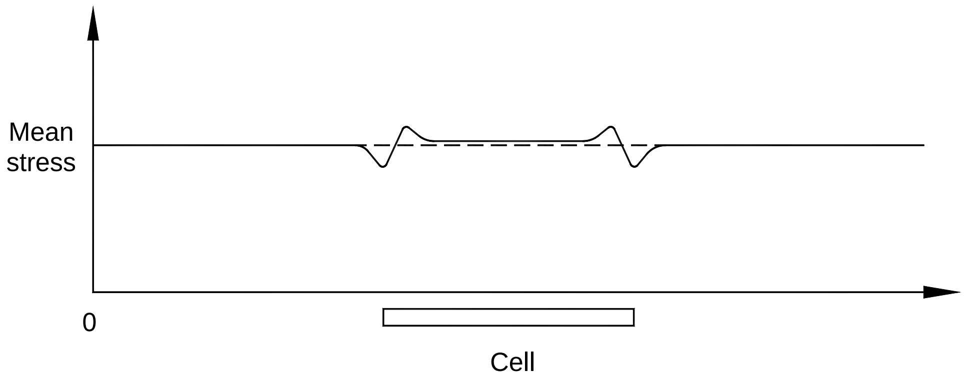


Figure 2.4 - stress redistribution - weak surrounding material with stiff cell a

2.5.5 In a stronger surrounding material the de-stressed zone around the edge of the cell is more extensive and hence at the center of the cell the degree of over-registration of the mean stress is greater. This is represented schematically in Figure 2.5.

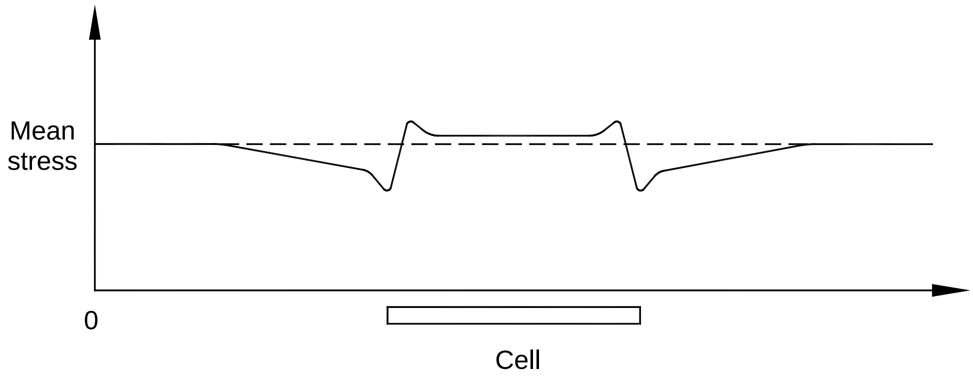


Figure 2.5 - stress redistribution -. Strong surrounding material with stiff cell

2.5.6 In a stiff surrounding material like concrete the cell may be less stiff (more compressible), in which case the cell will under-register the mean stress as the stress in the surrounding material tends to "bridge" around the cell. This is represented schematically in Figure 2.6.

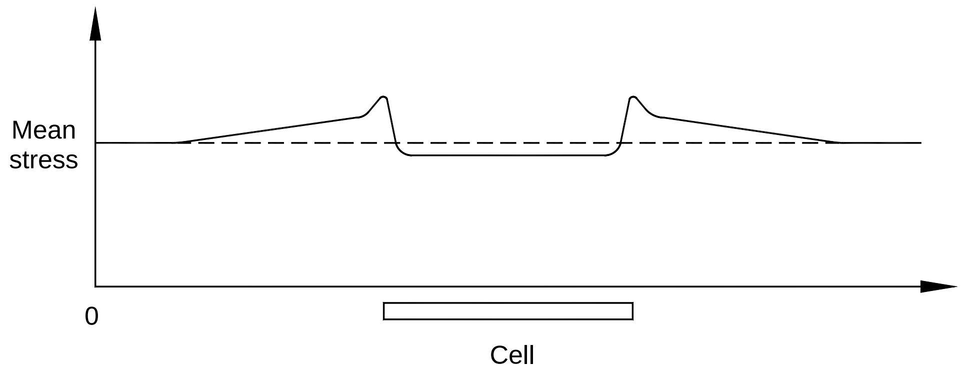


Figure 2.6 - stress redistribution - stiff surrounding material with weak cell

2.5.7 The last example (figure 2.6) is more applicable to concrete. Encardio-rite concrete pressure cells generally show a maximum degree of under-registration as 10% of the mean stress.

2.5.8 Any closed hydraulic system is sensitive to temperature effects. The stress cell when embedded in concrete acts like a closed hydraulic system. Any change in temperature of the surrounding concrete therefore gives an unauthentic or false reading, the magnitude of which depends upon the elasticity of the surrounding concrete and the relative coefficient of expansions of the materials in contact & the filled fluid inside the stress cell. In some cases this effect may be high enough to cause permanent damage to the pressure transducer and should be considered in determining the capacity of the sensor ordered. A thermistor is incorporated in each sensor to assist in determining temperature compensation factors that may be calculated by closely observing the in-situ stress cell performance.

2.6 Taking readings with the model EDI-54V vibrating wire indicator

The model EDI-54V vibrating wire indicator (figure 2.6 (a)) is a microprocessor-based read-out unit for use with Encardio-rite's range of vibrating wire sensors. It can display the measured frequency in terms of time period, frequency, frequency squared or the value of measured parameter directly in proper engineering units. It uses a smartphone with Android OS as readout having a large display with a capacitive touch screen which makes it easy to read the VW sensor.

Fig 2.6 (a) – Vibrating wire indicator

The EDI-54V vibrating wire indicator can store calibration coefficients from 10,000 vibrating wire sensors so that the value of the measured parameter from these sensors can be shown directly in proper engineering units. For transducers with built-in interchangeable thermistor, it can also display the temperature of the transducer directly in degree Centigrade.

The vibrating wire indicator has an internal non-volatile memory with sufficient capacity to store about 525,000 readings from any of the programmed sensors. Each reading is stamped with the date and time the measurement was taken.

Refer instruction manual WI-6002.112 of model EDI-54V for entering the transducer calibration coefficients. The gage factor of the model EPS-30V-C concrete pressure cell is given in the test certificate provided with every supply. The initial reading IR will be the actual reading in digits from the pressure cell after it is embedded and properly set in concrete.

An internal 6 V 4 Ah rechargeable sealed maintenance-free battery is used to provide power to the vibrating wire indicator. A battery charger is provided to charge the internal battery which operates from 90 V to 270 V AC 50 or 60 Hz V AC mains. A fully discharged battery takes around 6 hours to get fully charged. The indicator uses a smartphone as a readout that has its own internal sealed rechargeable Li-ion maintenance battery as a power source. A separate battery charger/adapter unit for the smartphone, operating from universal AC mains supply is supplied with each EDI-54V indicator unit.

The EDI-54V vibrating wire indicator is housed in an impact resistant plastic moulded housing with weatherproof connectors for making connections to the vibrating wire transducer and the battery charger.

2.7 Sample test certificate to be used with EDI-51V

Encardio-rite Electronics Pvt. Ltd.
A-7 Industrial Estate, Talkatora Road, Lucknow, UP-226011 India
E-mail: sales@encardio.com, encardio@sancharnet.in; Website: www.encardio.com
Tel. +91 (522) 2661039/40/41/42 Fax +91 (522) 2661043

TEST CERTIFICATE

DWT Traceable to standard no. NPL /3373/05/20/2002

Customer			
P.O.No.			
Instrument	Concrete Pressure cell	Date	01.03.2004
Serial number	4346	Temperature	23°C
Capacity	35kg/cm²	Atm. pressure	1.019kg/cm²

Pressure transducer calibration data

Input pressure kg/cm²	Observed value Up1 (Digit)	Observed value Down (Digit)	Observed value Up2 (Digit)	Average (Digit)	End Point Fit (kg/cm²)
0.0	6690.5	6687.9	6687.9	6689	0.000
7.0	6321.2	6328.7	6322.7	6322	7.140
14.0	5963.4	5969.2	5964.8	5964	14.097
21.0	5605.1	5608.4	5605.1	5605	21.078
28.0	5246.8	5249.6	5246.8	5247	28.042
35.0	4889.0	4889.0	4889.0	4889	35.000

Error (%FS) 0.40

Digit	f^2 X 10E-3	
Pressure transducer gage factor	1.944E-02	kg/cm²/digit
Thermal factor	0.008	kg/cm²/°C

Concrete pressure cell calibration data

Cell constant (multiplier)	1.007	
Linear gage factor	1.958E-02	kg/cm²/digit

Pin configuration/wiring code:

Red & black Signal Green & white Thermistor

Checked by Tested by

2.8 Sample calibration constants for EPS-30V-C to be used with EDI-54V

ENCARDIO RITE
Geotechnical, Structural and Environmental Monitoring Solutions

ENCARDIO-RITE ELECTRONICS PVT. LTD.
A-7, Industrial Estate, Talkatora Road, Lucknow, UP - 226011, India
P: +91 522 2661039-42 | F: + 91 522 2662403 | Web: www.encardio.com | E-mail: qc@encardio.com
CIN: U32109UP1966PTC003122 | NSIC: NSIC/GP/LKO/2015/0013524 | MSME: 09 02712 00221 dt. 16/01/2008 | D&B Rating: 4A1

Calibration Constants for EDI-54V Data Loggers

The constants will be used to read the Sensor Output in engineering unit (MPa)

Sl.No.	Pressure Sensor Sl. No.	Polynomial Constants				Linear Constants		
		A5,A3,A1	A4	A2	A0	A5,A4,A3,A1	A2	A0
1	43995	0	1.8362E-15	-4.6259E-07	2.5110E+00	0	-4.4249E-07	2.8314E+00
2	44006	0	1.9630E-16	-4.2461E-07	2.6567E+00	0	-4.2309E-07	2.6543E+00
3	44007	0	-2.9337E-16	-4.0744E-07	2.5885E+00	0	-4.1132E-07	2.6019E+00
4	44020	0	-1.9308E-16	-4.2233E-07	2.6675E+00	0	-4.2498E-07	2.6776E+00
5	44050	0	4.0604E-16	-4.4961E-07	2.8401E+00	0	-4.4592E-07	2.8302E+00
6	44066	0	3.5270E-15	-4.3925E-07	2.6177E+00	0	-4.0173E-07	2.5213E+00
7	44148	0	4.9612E-16	-4.5513E-07	2.8694E+00	0	-4.5044E-07	2.8609E+00
8	44155	0	2.2529E-15	-4.2783E-07	2.5889E+00	0	-4.0411E-07	2.5281E+00
9	44169	0	-6.8315E-16	-3.9056E-07	2.5110E+00	0	-3.9862E-07	2.5358E+00
10	44175	0	-4.9131E-17	-4.1682E-07	2.6646E+00	0	-4.1791E-07	2.6691E+00
11	44186	0	-1.8561E-15	-3.8740E-07	2.5307E+00	0	-4.0856E-07	2.5914E+00
12	44192	0	-9.7324E-16	-3.9361E-07	2.5154E+00	0	-4.0469E-07	2.5459E+00
13	44222	0	6.4001E-16	-4.1122E-07	2.5154E+00	0	-4.0489E-07	2.5608E+00
14	44255	0	7.2646E-16	-4.3504E-07	2.7026E+00	0	-4.2797E-07	2.6870E+00

(Q.C.Division)

Excellence through ingenuity since 1966

INTERNATIONAL: UAE | QATAR | BAHRAIN | GREECE | SINGAPORE | USA | BHUTAN
INDIA: LUCKNOW | DELHI | KOLKATA | MUMBAI | CHENNAI | BANGALORE | HYDERABAD | J&K

2.9 Sample calibration constants for EPS-30V-C to be used with ESDL-30

ENCARDIO RITE
Geotechnical, Structural and Environmental Monitoring Solutions
ENCARDIO-RITE ELECTRONICS PVT. LTD.
A-7, Industrial Estate, Talkatora Road, Lucknow, UP - 226011, India
P: +91 522 2661039-42 | F: + 91 522 2662403 | Web: www.encardio.com | E-mail: qa@encardio.com

Calibration Constants for ESDL-30 Series Data Logger

The constants will be used to read the Sensor Output in engineering unit (MPa)

Sl.No.	Pressure Sensor Sl. No.	Polynomial Constants			Linear Constants		
		A2	A1	A0	A2	A1	A0
1	43995	1.8362E-15	-4.6259E-07	2.5110E+00	0	-4.4249E-07	2.8314E+00
2	44006	1.9630E-16	-4.2461E-07	2.6567E+00	0	-4.2309E-07	2.6543E+00
3	44007	-2.9337E-16	-4.0744E-07	2.5885E+00	0	-4.1132E-07	2.6019E+00
4	44020	-1.9308E-16	-4.2233E-07	2.6675E+00	0	-4.2498E-07	2.6776E+00
5	44050	4.0604E-16	-4.4961E-07	2.8401E+00	0	-4.4592E-07	2.8302E+00
6	44066	3.5270E-15	-4.3925E-07	2.6177E+00	0	-4.0173E-07	2.5213E+00
7	44148	4.9612E-16	-4.5513E-07	2.8694E+00	0	-4.5044E-07	2.8609E+00
8	44155	2.2529E-15	-4.2783E-07	2.5889E+00	0	-4.0411E-07	2.5281E+00
9	44169	-6.8315E-16	-3.9056E-07	2.5110E+00	0	-3.9862E-07	2.5358E+00
10	44175	-4.9131E-17	-4.1682E-07	2.6646E+00	0	-4.1791E-07	2.6691E+00
11	44186	-1.8561E-15	-3.8740E-07	2.5307E+00	0	-4.0856E-07	2.5914E+00
12	44192	-9.7324E-16	-3.9361E-07	2.5154E+00	0	-4.0469E-07	2.5459E+00
13	44222	6.4001E-16	-4.1122E-07	2.5154E+00	0	-4.0489E-07	2.5608E+00
14	44255	7.2646E-16	-4.3504E-07	2.7026E+00	0	-4.2797E-07	2.6870E+00

(Q.C.Division)

3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for proper cable jointing and installation of the stress cell (also refer users manual on cable jointing - 6002.11:

3.1 Soldering iron 25 watt
3.2 Rosin 63/37 solder wire RF-3C, 30 swg
3.3 Thread sealant (Loctite 577 or equivalent)
3.4 Cable jointing compound (MS 853 and hardener MSH 283 - Mahendra Engineering & Chemical Products Ltd. or equivalent. For alternatives, refer to note on page 3-4 of Encardio-rite user's manual "cable jointing of sensors" 6002.11)
3.5 Acetone (commercial)
3.6 Spanner 28/32 and 38/40
3.7 Hacksaw with 150 mm blade
3.8 Hammer
3.9 Cable Cutter
3.10 Surgical blade with holder
3.11 Wire Stripper
3.12 Pliers 160 mm
3.13 Pouring funnel
3.14 Stainless steel rod 2 mm ϕ 150 mm length
3.15 Spatula
3.16 Rotary tin cutter
3.17 Fixture for jointing upto six concrete pressure cells (refer figure 3.1)
3.18 Toothbrush
3.19 Cloth for cleaning (lintless)
3.20 75 mm nails - around 10 per sensor
3.21 Crimping tool
3.22 Digital multimeter
3.23 Vibrating Wire Indicator EDI-54V

NOTE: A simple wooden fixture as shown below may be fabricated at site for faster cable jointing. It is also available from Encardio-rite.

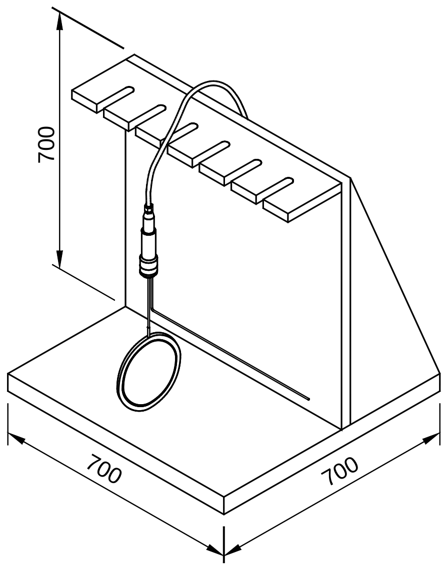


Figure 3.1

4 INSTALLATION PROCEDURE

4.1 Preparation of the sensor before installation

4.1.1 Remove cable joint housing from cable end of sensor. This gives access to the four pin terminal. Two of the terminals are marked with red and black colors. These are internally wired to the coil of the magnet assembly inside the sensor. The other two terminals are utilized for measurement of temperature using a thermistor. Clean the terminals with a toothbrush.

CAUTION: Do not use any acetone for cleaning as it may damage the glass to metal seal.

4.1.2 Check working of sensor as follows:

- Coil resistance measured by a digital multimeter between red and black pins, should lie between 120-150 Ohm. Determine resistance at room temperature from thermistor temperature chart in § 5. This resistance should be equal to that between pins marked green and white. For example, in case the temperature is 25°C, this resistance would be 3,000 Ohm.
- The resistance between any lead and the protective armour should be > 500 M Ohm.
- Connect sensor to Encardio-rite model EDI-54V portable readout unit and switch it on. The display will show something like:

```
Freq:  2629.8 Hz
```

2.3.4 Where the actual figure will vary depending on the transducer connected to the indicator.

2.3.5 For the stress cell, the initial reading (offset) in frequency should lie between 2,250 - 2,750 Hz. This initial reading on the portable readout unit should be stable.

- Check whether sensor is responding to changes in pressure. A crude but simple and very effective method of checking whether sensor is responding to changes in pressure is as follows:
  - Press diaphragm with thumb and verify that the frequency reading on the indicator decreases.
  - This change in reading ensures that the deformation produced by the pressure of the thumb on the diaphragm is transmitted to the vibrating wire sensing element.

4.1.3 Connect required length of cable to sensor as described in the operating manual on cable jointing - 6002.11.

NOTE: The cable should always be unreeled by turning the cable drum so that the cable is laid out on the flooring. Cables should never by unreeled by pulling on the cable itself as the internal conductors can get damaged from excessive strain.

Under no circumstances should the cable be unwound from any one side of the drum. This can happen, for example, when the cable drum is kept on its side and the cable is taken out without rolling the drum.

4.1.4 Check working of the sensor again following procedure described above in § 4.1.2.

NOTE: Remember to add the cable resistance when checking the resistance between the leads after the cable jointing. For the model CS 0401 cable, the resistance is 26 Ohm/km and for the model CS 0406 cable, the resistance is 48 Ohm/km. (multiply by 2 for both leads). In case any other cable is used, make the necessary addition in the resistance value.

4.1.5 Cable should be marked with permanent markers every 5 m by use of stainless steel tags tied by stainless steel wire stamped with appropriate concrete pressure cell number. Alternatively, plastic tabs are also available. Temporary identification can be done by writing serial number of sensor, its code number and location at which it is installed, on a strip of paper, placing strip on cable and covering it with a transparent plastic cello tape. Permanent identification is necessary to prevent errors in making proper connections in junction box and to insure correct splicing if cable is cut or broken.

CAUTION: Single most important factor leading to loss of worthwhile data from sensors is losing track of identification of cable ends. Proper identification and marking of cables is not to be taken casually. Care should also be taken to put an identification tag at point where cable comes out of structure such that cable identity is not lost if cable gets accidentally cut.

4.2 Installation of concrete pressure cell in concrete dam

Method of installation of concrete pressure cell in a concrete dam is described below. The same method may be adopted to your particular application to be used for other installations.

Installing concrete pressure cell is a fairly simple operation. In case effective stress is to be determined, a pore pressure meter must be installed close by. A concrete pressure cell is normally installed with the flat surfaces horizontal to measure vertical stress. However, it can be placed at other orientations inside fill, to measure stress in other directions i.e. a cell placed with flat surfaces vertical will measure horizontal stress in a direction perpendicular to diaphragm of the cell.

NOTE: Concrete pressure cell measures the total stress. In case effective stress is to be measured a pore pressure meter must be installed close by.

4.2.1 Allow for filling of dam to continue to an elevation of around 25 cm higher than where concrete pressure cell is to be mounted, leaving a 1 m x 1 m x 25 cm deep trench at position where sensor is to be finally placed. A larger trench may be left in case concrete pressure cell is to be installed along with other sensors, specially strain rosette and no stress strain gage that require much more space.

4.2.2 Prepare concrete surface of the 1 m x 1 m sensor trench by smoothing it off and flattening it as much as possible with any available hand tool, chisel or hammer. Hammer or grout 75 mm nails around 25 mm deep into the surface of the trench to mark the periphery around the sensing diaphragm and the pressure transducer. Alternatively, little pieces of small diameter reinforced bars may be grouted in bore holes drilled adjacent to the location where the cell would be located.

4.2.3 Carefully bend the pinch tube such that when the stress cell is installed, it will protrude out from the top. It can also be wrapped in foam etc. such that it can be easily retrieved later on.

NOTE: Record initial reading and temperature with EDI-54V for permanent record, when cell is placed in position and is about to be covered with fill material. This will form the zero reading for the stress cell. Note the barometric pressure at time of taking the initial reading.

4.2.4 To accommodate irregularities in concrete surface, it is necessary to fill space between surface and cell with quick setting mortar (see figure 4.1 on next page). Trowel a quick setting mortar pad around 30 mm deep on the surface of concrete in the trench. Press down the cell onto the pad with a little rotary motion of hands, causing the mortar to extrude sideways thus eliminating any air bubbles or spaces between the cell and the ground. Grip the cell firmly by bending the nails or the reinforced bars on the sides of the cell. Be careful that in doing this, the cell is not damaged. This can be verified by comparing the zero reading with the initial offset (see § 4.1.2).

4.2.5 Using a hand shovel, cover the concrete pressure cell with the quick setting mortar and fill the 25 cm. trench with concrete. Compact with a light duty pneumatic or petrol backfill tamper, taking care that the sensor remains well protected.

2.3.6 A weighted tripod can be used to hold stress cell in place until concrete hardens. The pinch tube is arranged to protrude above the bonding layer and when concrete has hardened it is used to pressurize cell and ensure good contact between cell and surrounding concrete.

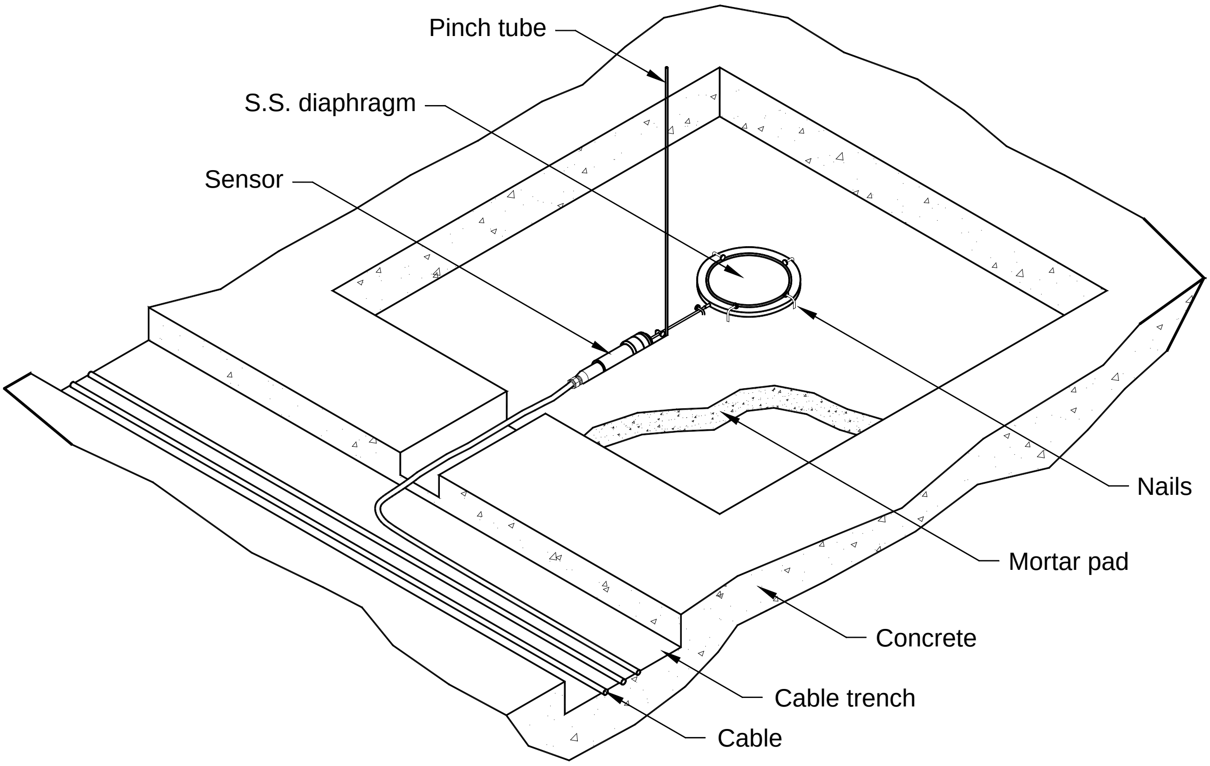


Figure 4.1

4.2.6 Once concrete sets, cell can be inflated using pinch tube and a special crimping tool. Connect cell to readout unit and gently squeeze pinch tube flat, using tool. Start squeezing around 25 mm from capped end and proceed downwards towards concrete layer. In case cell diaphragm is in good contact with concrete, pinching will immediately cause a pressure rise in the cell. Stop pinching. However in case cell diaphragm expands inside any space that may exist, pressure rise accompanying each pinch will be small. As soon as cell starts to fill space, pressure rise with each pinch will become larger.

2.3.7 Graph of readings would show a pronounced "knee" where contact between cell diaphragm and concrete is made. As soon as this "knee" is passed, squeezing of pinch tube should be immediately stopped. Bend pinch tube out of way such that it lays flat on concrete surface.

CAUTION: Do not squeeze pinch tube closer than 25 mm from end; otherwise seal plugging end of tube could be damaged. As tube is progressively squeezed flat, fluid is forced out of pinch tube into cell and pressure will rise. It is necessary to make a chart showing relationship between length of flattened pinch tube and corresponding pressure reading.

CAUTION: Continued pinching after the cell has made good contact would result in the reduction of the useful range of the stress cell. It can also cause the concrete around the cell to split open which is not desirable and could lead to erroneous readings.

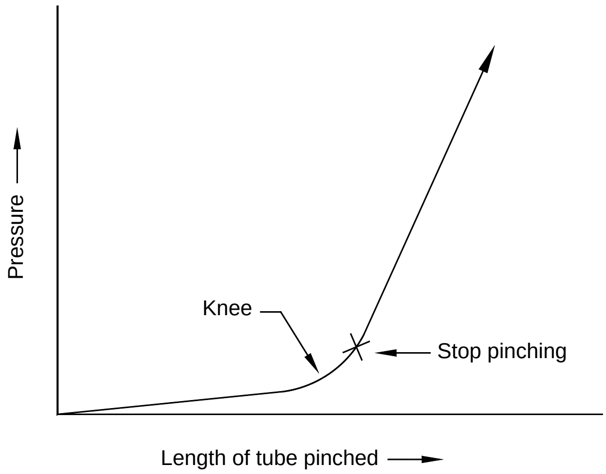


Figure 4.2

4.2.7 Record new initial stress reading with EDI-54V after cell has stabilized.

NOTE: First layer of material over sensor diaphragm was around 200 mm high. Similar layers of material should be put over this and compacted properly until at least 600 mm of material has been placed. Rubber tired equipment can now cross this location, but no vibratory rollers should be permitted over the sensor until a compacted thickness of at least 1 m is laid.

4.3 Cable laying in concrete dam

Very careful and skilled cabling is required in installation of the concrete pressure cell as the sensor/cable joint and a large part of the cable is permanently embedded and no future access is available for any maintenance and corrective action (see figure 4.4).

Procedure for laying of cables differs with individual installations. In general, however, all installations have following common requirement:

- The cable must be protected from damage by angular and sharp particles of the material in which the cable is embedded.
- The cable must be protected from damage by vibrators and compaction equipment.
- The cable must be protected from any possible stretching. Special care should be taken in case it has to be routed through different blocks.
- Cables may be spliced without affecting the sensor reading; nevertheless splicing should be avoided wherever possible. If necessary, use special cable jointing kits available from the factory.

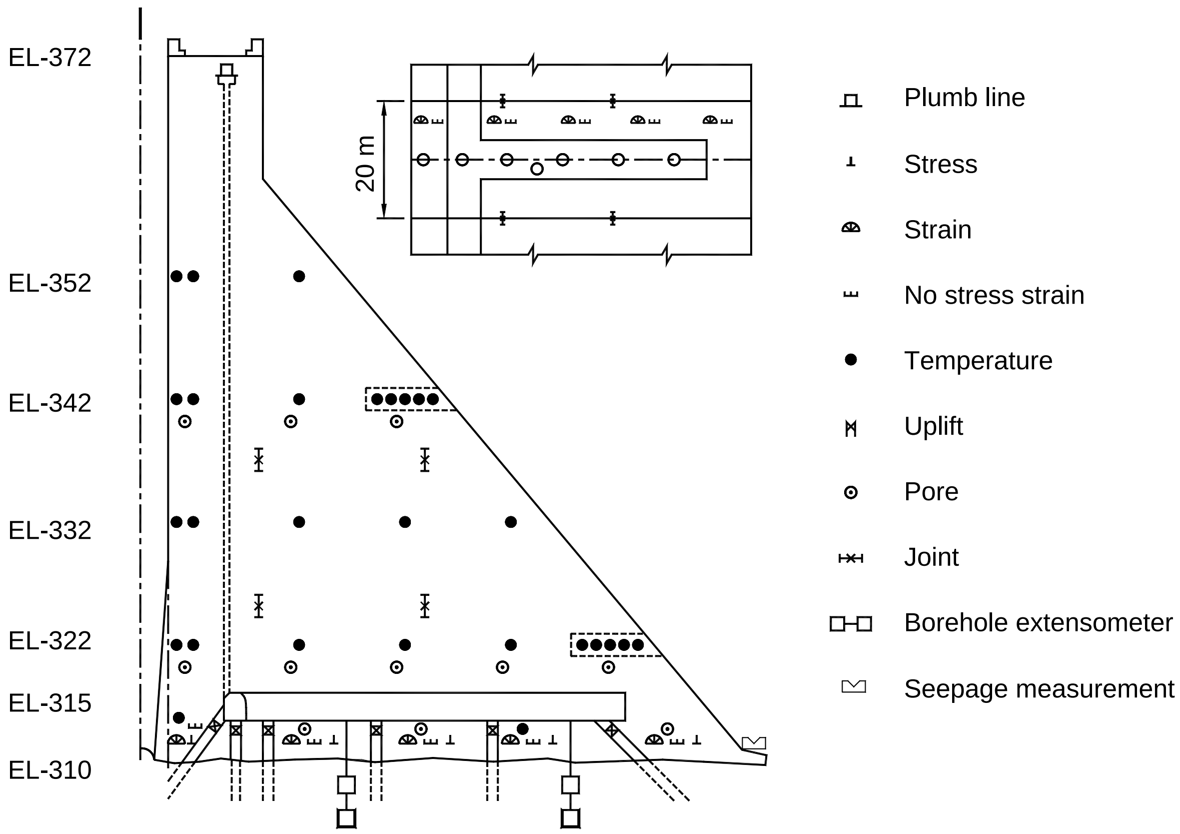


Figure 4.3

In a concrete dam, a number of concrete pressure cells along with other sensors are installed at selected elevations at different cross sections, as illustrated in figure 4.3 above. For example, three pore pressure meters, five strain rosettes, five no stress strain containers, five stress cells and two temperature meters are installed at elevation 312 m. Cables from these sensors have to be taken to junction boxes to be mounted inside one of the cross galleries. The gallery may be above or below the elevation at which the sensors are to be installed. As a general practice, all cables from sensors at any particular elevation are routed to a vertical shaft on the upstream side of the dam. The cables are then lowered or lifted through the vertical shaft to the gallery.

Refer to figure 4.4 for details of cable trench/channel for routing the cable from sensors. The cable from the sensors should be routed through a carefully marked channel trench ending into the vertical shaft and running parallel to the line of sensors. Depth and width of channel trench depends upon number of cables trench has to carry. In case all cables at an elevation fit in one row, depth of channel can be around 10 cm. If more than one row is required to lay all cables, the depth should be increased by 10

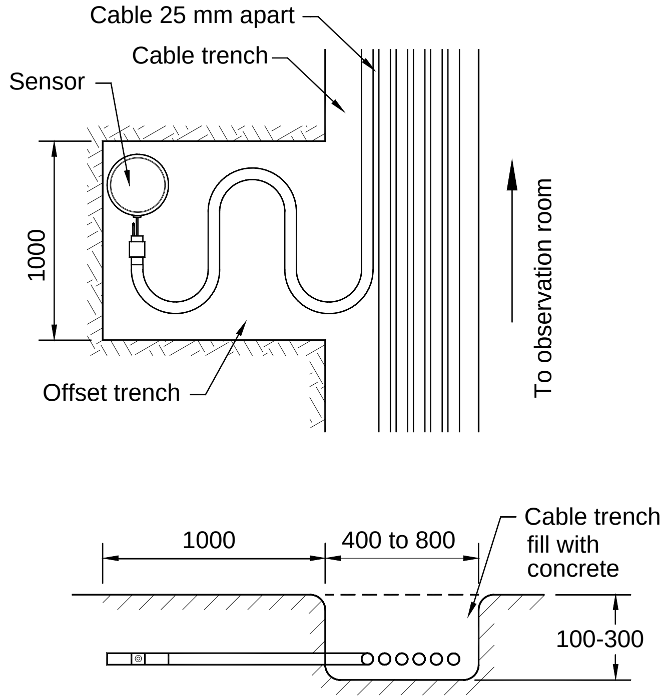


Figure 4.4

cm per row. The channel trench should be properly cleaned and leveled. Any sharp rocks or objects should be removed to prevent the cable from accidentally getting damaged when it is laid.

As access galleries are available in concrete dams, the cable from the sensors is first routed to the gallery. These cables may be terminated in junction boxes inside the gallery. The data from the various sensors can then be taken or logged from the junction boxes with the help of a read out unit or data logger. Alternatively, if required, the signals from the junction boxes may be carried through multi core cables to any observation room outside the dam structure.

The center distance between successive cables in cable trench should be kept at a distance of 25 mm. After laying the cables in any row, it should be covered with concrete by a hand shovel to a depth of around 10 cm and allowed to set. This is necessary to prevent any accidental damage to the cables.

Cables coming out of the sensors into the cable trench should be properly tagged. With the best possible precautions, mistakes may still occur. Tags may get lost due to the cable getting accidentally cut. Encardio-rite uses the convention that looking from the end of the trench towards the sensor, the cable from the most distant sensor is always at the left hand side and the offset trenches are to the right of the cable trench. In that order, the cable from the closest sensor is at the extreme right.

NOTE: A simple code for remembering this is "LL-SR". Longer (cable) left, shorter (cable) right when viewing the sensors from the observation room.

CAUTION: All cables should be properly identified by tagging them every 5 m, onwards from the point from which they come out of the dam body. The tags should be of a non-corrosive material like stainless steel or plastics.

Similar precautions must be taken when the cables come out from the cable trenches into the vertical shaft. Encardio-rite uses the convention that looking from the vertical shaft end towards the sensor, the cable from the most distant sensor is always at the left hand side. In that order, the cable from the closest sensor is at the extreme right. It is good practice to grout the cable in the vertical shaft at 2 m distances such that the left to right alignment is maintained.

As an Encardio-rite convention, again, the cable from the most distant sensor at any elevation should be connected to the extreme left socket in the junction box. Succeeding cables from the sensors are connected progressively towards the right in the junction box.

CAUTION: Care should be exercised when installing instrument cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run with AC power lines. Instrument cables will pick up 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading. Contact the factory concerning filtering options available for use with dataloggers and readouts should difficulties arise.

4.4 Measurement of earth pressure below raft foundations, floor slabs, pavements and footings etc.

Great care and good designing is required to measure interface earth pressure for this application. At first thought, one would install an interface pressure cell (model EPS-30/36-1/I) to measure the earth pressure. Under certain conditions, this is a solution. However, the problem faced could be as follows:

- The contact stress distribution may not be uniform due to varying properties of soil and varying degrees of its compaction. The contact stress at any location may not be typical of surrounding locations.
- A stress cell installed in soil at the interface could result in an irregular and inconsistent zone around the cell having different, more fine grained material under a lesser degree of compaction. This could be due to soil around stress cell being poorly compacted to avoid damage to it.

This is not a problem in an earth fill as earth above simply settles downward to fill voids and consolidate the ground. In a concrete slab immediately above interface cell this consolidation may not take place. Under influence of vibration, rain water or other factors, space around sensor may increase so that cell becomes loose from concrete above. In such a situation interface cell will register a very low stress that does not change as load increases.

A better solution is to use a concrete pressure cell with a pinch tube and cast it inside the concrete. Press the sensor on an initial concrete bonding layer spread over surface of the ground such that it is a little above the interface. Cover it with concrete. A weighted tripod may be used to hold sensor in position until concrete hardens. Use pinch tube to pressurize the stress cell and ensure good contact between cell and surrounding concrete after the concrete sets.

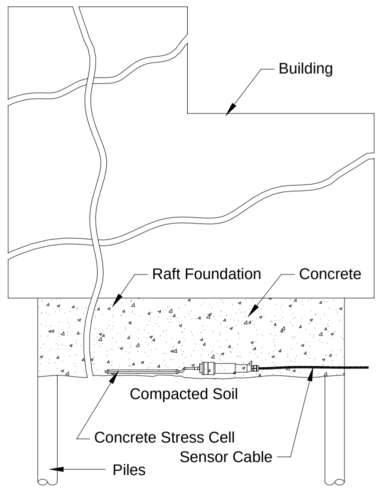


Figure 4.5

5 TEMPERATURE MEASUREMENT

5.1 Thermistor - temperature resistance correlation

Thermistor type: Dale 1C3001-B3 or equivalent

Temperature resistance equation

$$T = 1/[A + B(LnR) + C(LnR)^3] - 273.2\ ^oC$$

T = temperature in ^oC

LnR = Natural log of thermistor resistance

A = 1.4051×10^{-3}

B = 2.369×10^{-4}

C = 1.019×10^{-7}

Ohm	temp. ºC	Ohm	temp. ºC	Ohm	temp. ºC
201.1k	-50	16.60K	-10	2417	+30
187.3K	-49	15.72K	-9	2317	31
174.5K	-48	14.90K	-8	2221	32
162.7K	-47	14.12K	-7	2130	33
151.7K	-46	13.39k	-6	2042	34
141.6K	-45	12.70K	-5	1959	35
132.2K	-44	12.05K	-4	1880	36
123.5K	-43	11.44K	-3	1805	37
115.4K	-12	10.86K	-2	1733	38
107.9K	-41	10.31K	-1	1664	39
101.0K	-40	9796	0	1598	40
94.48K	-39	9310	+1	1535	41
88.46K	-38	8851	2	1475	42
82.87K	-37	8417	3	1418	43
77.66K	-36	8006	4	1363	44
72.81K	-35	7618	5	1310	45
68.30K	-34	7252	6	1260	46
64.09K	-33	6905	7	1212	47
60.17K	-32	6576	8	1167	48
56.51K	-31	6265	9	1123	49
53.10K	-30	5971	10	1081	50
49.91K	-29	5692	11	1040	51
46.94K	-28	5427	12	1002	52
44.16K	-27	5177	13	965.0	53
41.56k	-26	4939	14	929.6	54
39.13K	-25	4714	15	895.8	55
36.86K	-24	4500	16	863.3	56
34.73K	-23	4297	17	832.2	57
32.74K	-22	4105	18	802.3	58
30.87K	-21	3922	19	773.7	59
29.13K	-20	3748	20	746.3	60
27.49K	-19	3583	21	719.9	61
25.95K	-18	3426	22	694.7	62
24.51K	-17	3277	23	670.4	63
23.16K	-16	3135	24	647.1	64
21.89K	-15	3000	25	624.7	65
20.70K	-14	2872	26	603.3	66
19.58K	-13	2750	27	582.6	67
18.52K	-12	2633	28	562.8	68
17.53K	-11	2523	29	525.4	70

5.2 Measurement of temperature

Thermistor for temperature measurement is incorporated in the sensor. The thermistor gives a varying resistance output related to the temperature (see § 5.1). The thermistor is connected between the green and white leads. The resistance can be measured with an Ohmmeter. The cable resistance may be subtracted from the Ohmmeter reading to get the correct thermistor resistance. However the effect is small and is usually ignored.

The Encardio-rite model EDI-54V read-out unit gives the temperature from the thermistor reading directly in engineering units.

5.3 Temperature correction

A pressure-temperature variation correlation factor (k) is provided in the test certificate for the pressure sensor of concrete pressure cell. In case correction for temperature effect is required in cell, use following equation:

$P_{correction}$ = K (current temperature - initial temperature)

The temperature correction value is added to the pressure value read from the EDI-54V portable read-out.

The effect of the temperature coefficient of expansion of concrete on the stress cell is almost impossible to determine. Temperature effect caused by mismatch between the temperature coefficient of cell and surrounded concrete is not quantifiable and hence no correction factor for this effect is supplied. If required, user may conduct his own tests under controlled conditions. Please once read again § 2.5.8 in this connection.

6 OTHER CONSIDERATIONS/TROUBLE SHOOTING

6.1 Barometric pressure correction

The pressure transducer used in the Encardio-rite vibrating wire concrete pressure cell is evacuated and hermetically sealed and will respond to barometric pressure fluctuation. In fact all concrete pressure cells will respond to barometric pressure fluctuations unless they are manufactured in the gage pressure version and a capillary tube is provided in the cable which opens into the atmosphere.

Since the magnitude of barometric pressure fluctuations is of the order of +/-0.03 kg/cm^2, correction is generally not required. If a correction for these fluctuations is required then it is necessary to record the barometric pressure at the time of taking the reading. The initial barometric pressure corresponding to the zero reading at the time of installation is to be considered (refer to second note in § 4.2). The correction can be made by using the following equation:

$P_{correction}$ = (initial barometric pressure - current barometric pressure)

The pressure correction value is added to the pressure value read from the EDI-54V portable read-out.

6.2 Pressure conversion table

The test certificate gives the calibration coefficients suitable for reading in kg/cm^2. To convert the output to other engineering units, multiply the reading obtained from the model EDI-54V portable read-out unit in by the conversion factor given below:

bar	0.981
atm.	0.968
mm Hg	735.6
" Hg	28.96
psi	14.22
" H2O	393.7
'H2O	32.81
m H2O	10
Newton/cm2	9.807
kPa	98.07
mPa	0.098

6.3 Trouble shooting

Concrete pressure cell is embedded in concrete. Once installed, the cell is usually inaccessible and remedial action is limited. Maintenance and trouble shooting is consequently confined to periodic checks of cable connection and functioning of the read-out unit. Refer the following list of problems and possible solutions should problems arise. For any additional help, consult the factory.

6.3.1 Symptom: pressure cell reading unstable

- Check the insulation resistance. The resistance between any lead and the protective armour should be > 500 m Ohm. If not, cut a meter or so from the end of cable and check again.
- Does the read-out work with another concrete pressure cell? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.

- Check if there a source of electrical noise nearby? General sources of electrical noise are motors, generators, transformers, arc welders and antennas. If so the problem could be reduced by shielding from the electrical noise.

6.3.2 Symptom: pressure cell fails to read

- The cable may be cut or crushed? Check the nominal resistance between the two gage leads using an Ohm meter. It should be within 120 - 150 Ohm. The correct value is given in the concrete pressure cell test certificate. Please add the cable resistance when checking. For the model CS 0401 cable, the resistance is 26 Ohm/km and for the model CS 0406 cable, the resistance is 48 Ohm/km. (multiply by 2 for both leads). In case any other cable is used, make the necessary addition in the resistance value. If the resistance reads infinite or a very high value, a cut in the cable is suspected. If the resistance reads very low (<100 Ohm), a short in the cable is likely.
- Does the read-out work with another concrete pressure cell? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.