

भारतीय मानक

कंक्रीट और चिनाई वाले बाँधों में छिद्र दाब मापन युक्तियों के  
संस्थापन, रखरखाव और प्रेक्षण — रीति संहिता

भाग 2 कम्पन तार किस्म के सेल

*Indian Standard*

INSTALLATION, MAINTENANCE AND OBSERVATIONS  
OF PORE PRESSURE MEASURING DEVICES IN  
CONCRETE AND MASONRY DAMS —  
CODE OF PRACTICE  
PART 2 VIBRATING WIRE TYPE CELL

ICS 93.160; 91.220

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## FOREWORD

This Indian Standard ( Part 2 ) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydraulic Structures Instrumentation Sectional Committee had been approved by the River Valley Division Council.

Stress and stability analysis of concrete and masonry dams is carried out by considering the existence of uplift across different horizontal planes, having uplift intensity-distribution in accordance with the design criteria in practice. The effect of the uplift is to induce instability on account of resulting buoyancy in weight of the material in dam above the horizontal section under consideration.

Arrays of pore pressure cells in concrete and masonry at different elevations, spaced at suitable distances from the upstream face, would provide information on the status of pore pressure at the time of observation.

Large concrete and masonry dams are provided with a row or rows of internal formed drains. A record of the pore pressure development and its variations would indicate the effectiveness and adequacy of these drains. At the same time, any sudden and significant variations in the pore pressure development may be indicative of some structural damage or deficiency in the dam material, warranting timely remedial measures being undertaken.

For measuring the pore pressures in the body of concrete and masonry dams, the following device/instruments are used:

- a) Uplift pressure pipes; and
- b) Electrical pressure cells which may be of two types, namely
  - 1) Electrical resistance type pore pressure cells, and
  - 2) Vibrating wire type pore pressure cells.

Uplift pressure pipes and electrical resistance type pressure cells are covered in IS 6532:1972 'Code of practice for design, installation, observation and maintenance of uplift pressure pipes for hydraulic structures on permeable foundations' and IS 8282 ( Part 1 ) : 1976 'Code of practice for installation, maintenance and observation of pore pressure measuring devices in concrete and masonry dams: Part 1 Electrical resistance type cell' respectively. This standard, Part 2 covers the vibrating wire type pressure cells only.

In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries. In addition, the practices in the field in this country have also been considered.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( revised )'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# INSTALLATION, MAINTENANCE AND OBSERVATIONS OF PORE PRESSURE MEASURING DEVICES IN CONCRETE AND MASONRY DAMS — CODE OF PRACTICE

**PART 2 VIBRATING WIRE TYPE CELL****1 SCOPE**

This standard ( Part 2 ) covers the details of installation, maintenance and observation of vibrating wire type pore pressure measuring cells in concrete and masonry dams.

**2 REFERENCES**

The Indian Standard IS 10334:1982 'Code of practice for selection, splicing, installation and providing protection to the open ends of cables used for connecting resistance type measuring devices in concrete and masonry dams' is a necessary adjunct to this standard.

**3 INSTRUMENT****3.1 Vibrating Wire Type Pore Pressure Cell — Operating Principle**

The basic principle of the vibrating wire transducer is that the change in natural frequency of stretched wire depends on the change of the tension in the wire. In this instrument, one end of the gauge wire is attached to the centre of circular membrane and the other end is secured to the top of the transducer housing.

Fluid pressure applied to the membrane causes deflection of the membrane with consequent change in the tension of the wire and its resonant frequency. Thus the frequency of the gauge wire is a measure of the deflection of the membrane which is proportional to the pressure change.

**3.1.1** The main advantages of vibrating wire type instruments are given below:

- a) Easy to read.
- b) Effects of signal cable resistance, contact resistance, leakage to ground or length of signal cable are negligible.
- c) Frequency signal permits data transmission over long distance and thus suitable for remote observation.

**4 NUMBER AND LOCATION**

Representative blocks of the dam should be selected for the installation of these cells. Generally one of the deepest overflow and non-overflow sections should be selected for instrumentation. The cells should be installed in two or three levels in rows. The bottom row of pore pressure cells may be located a little above the foundation level ( say about 1.5 m ) or as may be required by the design. The second row may be installed at one-third or half the height of the dam. The spacing of the cells in each row may be 10 to 15 metres along the width of the dam.

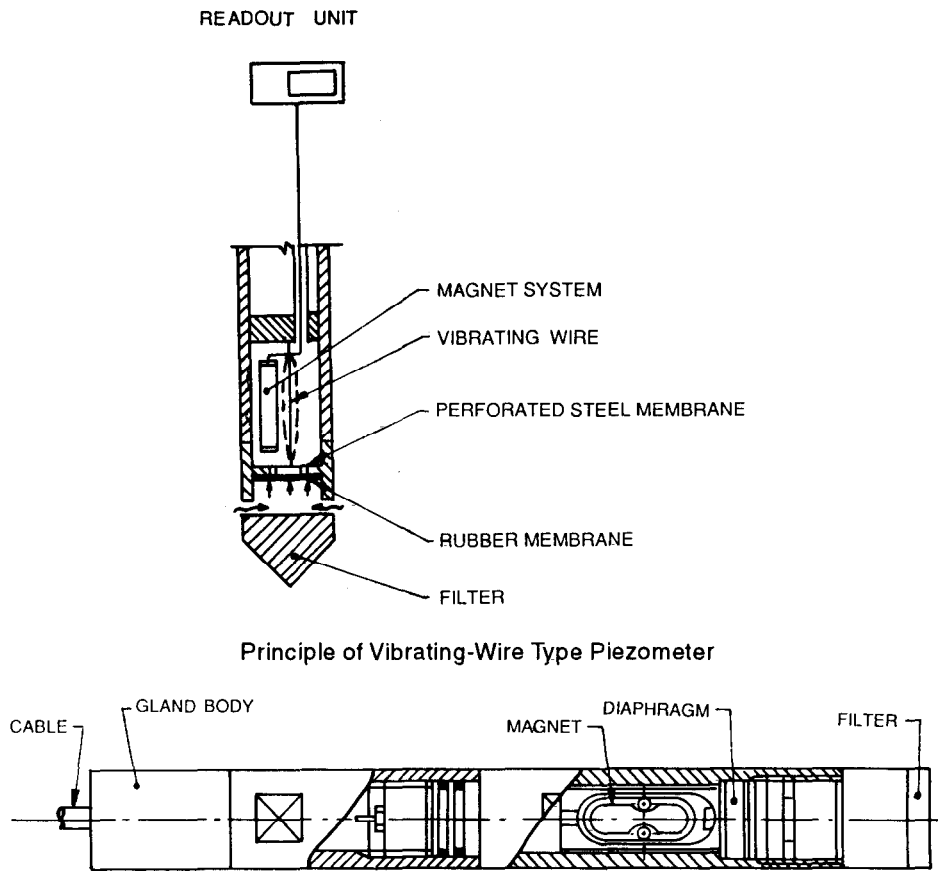
**5 EQUIPMENT**

The equipment consists of vibrating wire type pore pressure transducer, a signal cable and a frequency indicator/read out unit.

**5.1 Transducer**

A typical vibrating wire type piezometer assembly is illustrated in Fig. 1.

The pressure transducer consists of a hollow cylindrical body made of non-corrodable metal like ferro-manganese, bronze or stainless steel. The body houses a stainless steel membrane to which one end of the vibrating wire element is secured. The other end of the vibrating wire element is secured to the body. Close to this wire element a magnet assembly is mounted. Cable connections are taken out from the magnet assembly through the top end of the piezometer body and sealed with protective seal to prevent leakage of water to the vibrating wire assembly. The magnet assembly connected through the cable to the frequency indicator should be capable of exciting and picking up the frequency of vibrations that are read on the indicator. The transducer should incorporate suitable diodes for over-voltage protection to avoid damage from transient voltages and lightening, etc.



Principle of Vibrating-Wire Type Piezometer

FIG. 1 TYPICAL VIBRATING WIRE TYPE PIEZOMETER ASSEMBLY

The lower end of the transducer body houses a filter element of low or high air entry value. The filter elements should be made of either Sintered Bronze or Ceramic.

The permeability and bubbling pressure ( pressure of entry of air ) of filter element should be as follows:

Material	Permeability	Bubbling Pressure
Sintered bronze	$10^{-3}$ cm/s	0.1 bar
Ceramic	$10^{-5}$ cm/s to $10^{-7}$ cm/s	1 bar to 4.5 bar

The diameter of the piezometer should generally be 32 mm for normal applications. In special cases piezometer of other diameters, say, 42 mm or 78 mm may be used.

The working range of the piezometer should be up to 20 bar. However, capacities up to 60 bar may be used for special applications. The accuracy of the vibrating

wire piezometer shall be  $\pm 0.1$  percent of full range.

5.2 Signal Cable

Cable to connect the transducer to the readout unit should be selected depending on the environments in which the cable is laid.

For normal environment; cables with two core single pair cable with annealed copper conductors and with copper shielding; heavy PVC coating should be adequate. However in adverse environments, steel armoured petroleum jelly filled and polyethylene insulated cable should be used. Heavily armoured cables with 10, 20 or more pairs should be used to connect junction boxes to the instrument houses.

5.3 Readout/Data Logger

A simple, portable, battery operated readout unit with 4-Digit LCD display should be used. Calibration data for each transducer should be provided when a simple readout unit to ready frequency is used, for converting the frequency readings to relevant engineering units.

Readout units with facility to read the relevant engineering units directly on the display may be used in place of the frequency readout units.

Sophisticated Datalogging with Microprocessor/Microcontroller for remote sensing and centralised logging/controlling capabilities may also be employed.

## 6 CALIBRATION

Each transducer should be calibrated separately on a suitable calibrating system in the laboratory prior to taking the instrument to field for installation. It is not practicable to recalibrate a sensor after installation and therefore good long term stability of the sensors is important to obtain reliable results. The sensor should be capable of being overloaded to 1.5 times its rated capacity. While calibrating the sensors, the transducers should be over-loaded by 10 percent at least 10 times to stabilize the calibrated readings. Each transducer should be provided with a separate calibration certificate.

Usually the gauge wire and the body of the transducer are made of materials having similar coefficient of thermal expansion so that temperature variations, if any, have minor influence on the readings. The transducers are to be calibrated in various temperatures within its working range and the thermal coefficient should be recorded in calibration certificate.

## 7 INSTALLATION

### 7.1 Saturation

**7.1.1** The tip of the piezometer containing the filter element should be detached from the transducer. The ceramic element should be boiled in clean water for about 10 minutes. The water with the filter should then be cooled and the transducer body should be attached to the filter element under water. The assembly should be kept soaked in water for at least 24 h before installation. In case of Sintered Bronze element, only immersion in distilled water for about 30 min is sufficient.

If the piezometer is used in a borehole, the tip and filter should be covered by a rubber membrane to prevent escape of water from the filter element before the piezometer reaches the ground water level. A string should be connected to the end of this rubber membrane for pulling the membrane off the filter element when the water level is reached.

### 7.2 Placement of Piezometer

**7.2.1** The pore pressure cells are usually located

near the top of a lift, where placement can be accomplished after concreting in the area has been completed. A hole just large enough to accommodate the instrument and about 300 mm deep should be dug at the desired location. Fine sand cushioning should be provided before placing mortar around the instrument.

**7.2.2** Frames or brackets to hold the cell in position during embedment, should not be used, since these would possibly provide a leakage path directly, to the cell. Concrete or mortar (as the case may be) should be placed by hand around the instrument and tamped lightly so as to obtain contact between the body of the cell and the surrounding concrete/masonry. Excessive tamping of the concrete/masonry should be avoided as this would result in a highly impermeable zone around the cell and affect the normal build-up of hydrostatic pressure. After embedment, a temporary cover of boards laid over the cell locations provide protection until the concrete/mortar has hardened. The ends of cables attached to the pore pressure cells which remain uncovered for a while until these are properly terminated in a terminal board, should be protected by cable protection caps. This precaution is considered necessary with a view to prevent moisture and water entering the pore pressure cells through the cable ends.

### 7.3 Cables and Conduits

It is advisable to calculate in advance the exact length of cable required to be attached with each of the cells as the splicing should be avoided to the extent possible.

**7.3.1** In estimating the length of the cable to be added, a suitable route between the point of embedment of the instrument and the terminal station in the gallery should be selected by study of the drawings. In selecting the route, due consideration should be given to the construction procedures involved in placing the concrete/masonry where the instrument is to be embedded and to possible obstructions along the chosen route. After the selected route has been verified, the length of the cable required should be estimated, and a small amount usually 10 percent or 2 m, whichever is larger, should be added to allow for extra length required due to normal variations from the selected route. The length of the cable should be limited as far as possible. In any case it should not exceed 80 m.

**7.3.2** In general, cables are run horizontally without conduit in the concrete and in conduits in the masonry and run in downward and upward

directions in conduits both in the concrete and the masonry. The conduit may be of any material which will not collapse in the fresh concrete/masonry. The size of the conduit may be chosen in accordance with the procedure given in IS 10334 : 1982.

**7.3.3** If the cable leads are to cross contraction joints in the structure, a slack cable recess should be provided at the crossing point. This may consist of a wooden box block out, forming a recess into which the cable is run. During placement of concrete/masonry in the adjacent block, a 300 mm loop of slack cable should be left in the unfilled block out and the remaining length of cable laid in the usual manner.

**7.3.4** Cables should be threaded individually into the conduit, so that each cable could support its own weight. At the entrance of the cables into the conduits suitable protection such as padding with burlap, should be provided around each cable and in the interstices between the cables to prevent sharp bends and to prevent the entry of concrete/mortar and grout into the conduit.

**7.3.5** Group of cables running horizontally in a concrete lift may be taped together at intervals and laid on the top of the last but one layer of concrete in the lift, covered with pads of fresh concrete/mortar at several points along the length. The placement of the final concrete lift layer should be allowed to proceed in the normal manner.

**7.3.6** The layout should be so planned that cells and terminal boxes are located in the same block.

**7.3.7** In cases where a number of cables from widely spread points are collected at one central point and run downward into a conduit, a very successful plan is to run the cable in two steps. A collecting box or concrete form is erected around the grouped conduits so that the lift is left about 450 mm low at the conduits. During the placement of the concrete in which the cells are embedded, the cables are brought horizontally to the collection point, coiled and hung out of the fresh concrete. As soon as the concrete has set sufficiently to bear traffic, the cable coils are taken down the conduit to the terminal boxes. The advantage is that it is much easier to sort out and run the cables when they are not muddled with fresh concrete/mortar.

#### **7.4 Identification of Cables and Cells**

Each cell should be identified by some kind of code number. A preferable identification mark is a letter prefix designating the type of instrument and numbered

consequently. The normal prefix used for pore pressure cells is PP. When the cable lead is connected to a cell, an identification band with the instrument identification number should be stamped or punched on it and crimped to the cable about 900 mm from the cell. A similar band should be crimped about 300 mm from the free end of the cable. In addition a few more markers, consisting of the identification number marked on white tape and covered with linen and friction tape, should be placed around the cable near the reading end.

#### **7.5 Terminal Boxes**

##### **7.5.1 Location of Terminal Boxes**

Permanent facilities for taking readings are provided in terminal recess usually located in blockouts on walls of galleries nearest to the instruments. The reading stations for all embedded instruments in a monolith should be located in same monolith if possible, to avoid running of cable leads across contraction joints. Separate terminal recesses for cable leads from different types of instruments are not required. Where a gallery or similar semi-protected location is not available, a conveniently accessible exterior location may be selected and secured against unauthorized tampering.

##### **7.5.2 Lighting**

Normal gallery lighting is usually not adequate and a supplementary fixture for lighting should be provided at the terminal reading station.

##### **7.5.3 Moisture Prevention**

To reduce corrosion at the cable terminals and panel board connections, which is usually a serious problem in dam galleries, an electrical strip heater or incandescent lamp should be installed within the terminal recesses and permanently kept on. A bulb provided in the recess for lighting may also serve this purpose.

##### **7.5.4 Installing Terminal Equipment**

After all the cable leads have been brought into a terminal recess, the surplus lengths of cables should be cut off and the end of individual conductors prepared for permanent connection to the panel board or terminal strip. Proper care should be taken for identification of the cables and cells.

### **8 COLLECTION OF COMPLEMENTARY DATA**

**8.1** The collection of related and supporting data pertaining to structural behaviour is an integral part

of the instrumentation programme, and should proceed concurrently with the installation of the instruments and the readings of the embedded instruments. Types of information required to support or clarify the instrument observation results include the following:

- a) *Construction Progress* — schematic concrete/masonry placing diagram showing lift placement dates, concrete placing temperatures and lift thickness.
- b) *Concrete Mixes* — cement contents, water-cement ratios, and typical combined aggregates gradings for interior and exterior mixes.
- c) *Fine Aggregate* — typical fine aggregate gradings, before and after mixing.
- d) *Air Entrained* — amount of entrained air, admixture used, how introduced.
- e) *Cement Type* — source or sources, physical and chemical properties, including heat of hydration.
- f) *Aggregate* — types of geologic classification, petrographic description, sources, and chemical properties.
- g) *Curing and Insulation* — type and method of curing, type, location and duration of insulation protection, if any.
- h) *Pool Elevations* — daily reservoir and tailwater elevations.
- j) *Foundation Conditions* — final rock elevations, unusual geologic features.

Much of the information listed above will usually be available from investigations carried out prior to and during the project design stage or may be obtained under usual construction control operations.

**8.1.1** Observers should be alert to detect cracks or similar evidences of structural distress which may develop; and record time of occurrence, initial size and extent and subsequent changes in size and extent, and any corrective action taken.

## 9 OBSERVATIONS

**9.1** The readings of resonant frequency change should be taken with the help of readout unit.

The value of calibration factor  $K$  and the value of constant  $A$  provided by the instrument manufacturer by calibrating the instruments in the factory.

The values of  $K$  and  $A$  are substituted in the following formulae to arrive at the value of frequency  $F$  of the vibrating wire at ' $t$ ' °C.

$$P = K [(f_o^2 - f^2) + C(t - t_o)] \cdot A$$

where

$K$  = calibration factor (bar/ $H_z^2$ ),

$f_o$  = zero frequency ( $H_z^2$ ) at  $t_o$  °C,

$f$  = frequency, ( $H_z$ ) at  $t$  °C,

$P$  = pressure (bar) at  $t$  °C,

$C$  = coefficient of temperature  $H_z^2$ /°C,

$A$  = zero offset (bar),

$t_o$  = temperature of instrument at the time of calibration in °C, and

$t$  = temperature of instrument at the time of observation in °C.

**9.2** The observations of the pore pressure cells should begin as soon as the instruments are covered and may continue at gradually increased time intervals. The pore pressures within concrete/masonry develop slowly and occur only when hydrostatic head is sustained for an extended period against the upstream concrete/masonry surface. The pore pressure cells may be read initially at 1 to 3 h intervals after embedment and subsequent readings may be taken at weekly intervals after the reservoir level has reached the level of the instruments and until the operating reservoir elevation has been attained and twice monthly thereafter.

## 10 RECORD OF OBSERVATION AND METHOD OF ANALYSIS

The observations made of the embedded cells should be suitably recorded. A recommended proforma for the record of observations and for transfer of observations to a permanent record in office is given in Annex A. This data sheet form may be got printed in advance upon which the observations can be noted as they are taken and for preparation of permanent records.

Alternatively, if a Central Data Acquisition System is used, the data is automatically collected and presented in the formats required by the method of analysis used.

**ANNEX A**  
( Clause 10 )

**PROFORMA FOR RECORD OF OBSERVATIONS OF VIBRATING WIRE TYPE PORE  
PRESSURE CELL**

Project :

a) Instrument Name :

b) Instrument Manufacturer :

Location :

Initial frequency  $f_0$  :Calibration Temp ( $t_0$ ) :Calibration Factor ( $K$ ) :Temperature Coefficient ( $C$ ) :Zero Offsets ( $A$ ) :Pore Pressure  $P = K [ ( f_0^2 - f^2 ) + C ( t - t_0 ) ] + A$ 

<i>Date</i>	<i>R.W.L in m</i>	<i>Temp of Location of Cell (t)°C</i>	<i>Observed Frequency (f) Hz</i>	<i>Change in Frequency (f<sub>0</sub>-f)Hz</i>	<i>Pore Pressure (P) Bar</i>	<i>Pore Pressure in Metres of Water Head</i>	<i>Remarks</i>
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Observer's Signature:

Date:



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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards : Monthly Additions'.

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