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Indian Standard

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

PART I ELECTRICAL RESISTANCE TYPE CELL

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PART I ELECTRICAL RESISTANCE TYPE CELL

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 30 November 1976, after the draft finalized by the Hydraulic Structures Instrumentation Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Stress and stability analysis of concrete and masonry dams is carried out by considering the existence of uplift across every horizontal plane, having uplift intensity-distribution in accordance with the design criterion 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.

0.3 Provision of arrays of electric resistance type and vibrating wire type pore pressure cells in concrete and masonry at different elevations, and spaced at suitable distances from the upstream face, would provide information on the status of pore pressure at the time of observation.

0.4 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.

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

a) Pressure pipes; and

b) Electrical pressure cells of two types, namely, electrical resistance type pore pressure cells, and vibrating wire type pore pressure cells.

0.5.1 Pressure pipes and vibrating wire type pore pressure cells are proposed to be covered in separate standards. This standard covers the electrical resistance type pore pressure cells.

0.6 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 to relating it to the practices in the field in this country.

0.7 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, shall be rounded of in accordance with IS:2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part I) covers the details of installation, maintenance and observation of resistance type pore pressure measuring devices in concrete and masonry dams.

2. INSTRUMENT

2.1 Electrical Resistance Type Pore Pressure Cell — Resistance type of pore pressure cell utilizes the two electrical principles, namely, changes in tension in elastic wires cause change in electrical resistance of the wires and changes in temperature of wires cause changes in electrical resistance of wires. Details of a typical pore pressure cell are shown in Fig. 1. This instrument has a solid steel diaphragm which is actuated by the pressure of the pore fluid which filters through a porous plug. The deflection of the diaphragm is measured by means of a strain meter unit. The space between the porous plug and the diaphragm is filled with petroleum jelly or water before use so that the response is almost instantaneous. The readings are taken by test set working on Wheatstone bridge principle and recorded on a suitable data form.

3. NUMBER AND LOCATION

3.1 Representative blocks of the dam shall be selected for the installation of these cells. Generally the deepest overflow and non-overflow sections are selected. The cells are 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.

*Rules for rounding off numerical values (*revised*).

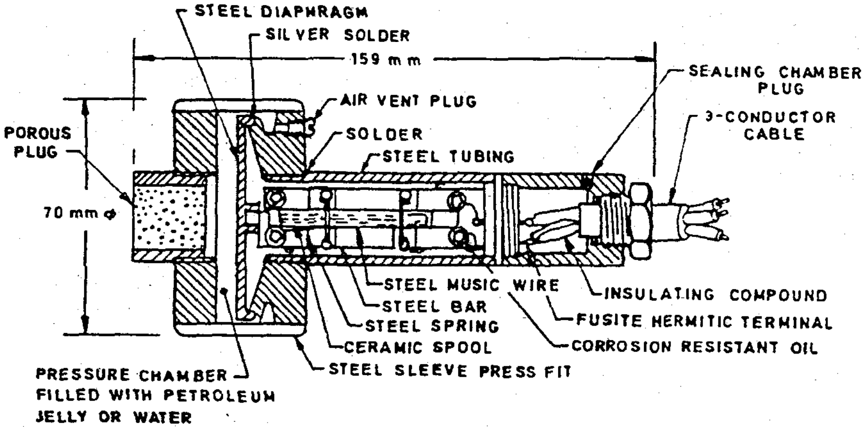

FIG. 1 TYPICAL RESISTANCE TYPE PORE PRESSURE CELL

4. INSTALLATION

4.1 Prior to the embedment of pore pressure cells in the newly placed concrete or masonry, each instrument should be thoroughly checked for cell resistance as also for the lead resistance and these should be entered in the pro forma given in Appendix A. The resistance and resistance ratio before splicing and after splicing should also be recorded in the pro forma given in Appendix A which is meant for recording pre-embedment test results.

4.2 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. The cell should be laid horizontally in the hole, normal to the exterior surface of the concrete and with the porous plug at the desired distance from the upstream surface.

4.2.1 Frames or brackets to hold the cell in position during embedment, should not be used, since they 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 shall be avoided as this would result in a highly impermeable zone around the cell and affect the normal build-up of hydro-static pressure. After embedment, a temporary cover of boards laid over the cell locations will afford 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, shall be protected by cable protection caps. This pre-caution is considered necessary with a view to prevent moisture and water entering the pore pressure cells through the cable ends.

4.3 Cables and Conduits

4.3.1 The pore pressure cells are normally supplied with about 750 mm of three conductor rubber covered cable attached to the instrument. Enough additional three conductor cable is then added in the field to reach from the point where the instrument is embedded to a terminal station in the gallery. The additional length of cable shall be attached to the pore pressure cells by means of splicing in accordance with the 'Indian Standard Code of practice for selection, splicing, installation, and providing protection to the open ends of the cable used for connecting resistance type measuring devices in concrete and masonry dams' (*under preparation*).

NOTE — Till such time the standard under preparation is published, the matter shall be as agreed upon between the concerned parties.

4.3.2 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 a study of the drawings. In selecting the route, due consideration shall 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 shall be estimated, and a small amount usually 10 percent or 2 m, whichever is larger, shall 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 shall not exceed 80 m.

4.3.3 In general, cables 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 the 'Indian Standard Code of practice for selection, splicing, installation, and providing protection to the open ends of the cable used for connecting resistance type measuring devices in concrete and masonry dams' (*under preparation*) (*see* Note *under* **4.3.1**).

4.3.4 If the cable leads are to cross, contraction joints in the structure, a slack cable recess shall 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 shall be left in the unfilled block out and the remaining length of cable laid in the usual manner.

4.3.5 Cables should be threaded individually into the conduit, so that each cable will be required to support only its own weight. At the entrance of the cables into the conduit 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 entrance of concrete, mortar and grout into the conduit.

4.3.6 Where a group of cables is to be run horizontally in a concrete lift, they 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 their length, and placement of the final concrete lift layer allowed to proceed in the normal manner.

4.3.7 The layout should be so planned that cells and terminal boards are in the same block as far as possible.

4.3.8 In cases where a number of cables from widely-separated 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 and there 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 boards. The advantages are that it is much easier to sort and run cables when they are not muddled with fresh concrete/mortar.

4.4 Identification of Cables and Cells — Each cell should be identified by 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 stamped or punched on it is crimped to the cable about 900 mm from the cell and a similar band 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.

4.5 Terminal Boards

4.5.1 *Location of Terminal Boards* — Permanent facilities for making 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 that monolith if possible, in order to avoid running 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 the facilities secured against unauthorized tampering.

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

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

4.5.4 *Installing Terminal Equipment* — After all 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 shall be taken for identification of the cables and cells (*see* **4.4**).

5. COLLECTION OF COMPLEMENTARY DATA

5.1 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 aggregate 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 use, how introduced.

e) *Cement Type* — source or sources, physical and chemical properties, including heat of hydration.

f) *Aggregates* — types, 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 will be obtained under usual construction control operations.

5.1.1 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.

6. OBSERVATIONS

6.1 The readings of resistance of the steel music wire of the cell and the resistance ratio should be measured using the test set working on the Wheatstone bridge principle.

6.2 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 after embedment and subsequent readings may be taken at weekly intervals after the reservoir level reaches the level of the instruments and until the operating reservoir elevation has been attained and twice monthly thereafter.

7. RECORD OF OBSERVATIONS AND METHOD OF ANALYSIS

7.1 The observations made of the embedded cells shall be suitably recorded. A recommended pro forma for the record of observations and for transfer of observations to a permanent record in the office is given in Appendices B and C. These data sheet forms may be got printed in advance upon which the observations can be noted as they are taken and for preparation of permanent records. The method of analysis of the data obtained by the observations of embedded pore cells is given in Appendix C.

8. SOURCES OF ERROR

8.1 The following are the sources of error and should be guarded against in the measurement of resistance type pore pressure cells:

a) Low voltage of test set batteries;

b) Loose connection of cable terminals on terminal panels;

c) Loose connections in the test set circuit;

d) High voltage resulting in heating of the wires and thus affecting the accuracy of the reading; and

e) Imperfect cable splice, resulting from improper matching of individual conductors, improper soldered connections or splice not rendered moisture-proof.

APPENDIX A

(*Clause* 4.1)

PRO FORMA FOR THE RECORD OF OBSERVATIONS RESISTANCE TYPE PORE PRESSURE CELLS PRE-EMBEDMENT TESTS

Project................................

Instrument No.

Manufacturer's No.............

Project No.........................

Location..............................

Air temperature...................

Wet bulb temperature...........

1. RESISTANCE BEFORE CABLE SPLICING

i) White-black

ii) White-green

iii) Green-black

iv) Resistance one pair

2. RESISTANCE RATIO (INSTRUMENT ONLY)

i) Direct ratio (white-green-black)

ii) Reverse ratio (black-green-white)

3. INDIVIDUAL CONDUCTOR RESISTANCE

i) Length

ii) Black

iii) Green

iv) White

4. RESISTANCE OF INSTRUMENT AFTER CABLE SPLICING

i) White-black

ii) White-green

iii) Green-black

iv) Resistance one pair

5. RESISTANCE RATIO (INSTRUMENT WITH CABLE)

i) Direct ratio (white-green-black)

ii) Reverse ratio (black-green-white)

Date of test:

Date of embedment:

NOTES:

Name and signature of observer

APPENDIX B

(*Clause* 7.1)

PRO FORMA FOR THE RECORD OF OBSERVATIONS RESISTANCE TYPE PORE PRESSURE CELLS FIELD READINGS AFTER EMBEDMENT

Project........................ Zero Reading

Instrument No.	Previous Reading			Current Reading				Reservoir Level	Observer's Signature
	Date	Resistance	Resistance Ratio	Date	Time	Resistance	Resistance Ratio		

APPENDIX C

(*Clause* 7.1)

PRO FORMA FOR PERMANENT RECORD OF OBSERVATIONS RESISTANCE TYPE PORE PRESSURE CELLS

Project.................................   Sheet No.. ....

Pore Pressure Cell No.............   Location..................................

Calibration Data:

Cell resistance at A°C*...................................(B*) ohms

Change in temperature per ohm change in resistance................................(C*) °C

Ratio at zero stress...%

Original calibration constant.........................(*) N/m^2 (kg/cm^2) per 0·01% ratio change

Calibration constant corrected for leads..............(D) N/m^2 (kg/cm^2) per 0·01% ratio change

Resistance of leads at.................°C.................ohms (pair)

Date	Time	Total Resistance Ohms	Lead Resistance Ohms	Cell Resistance Ohms	Temperature °C	Resistance Ratio %	Change in Ratio %	Indicated Hydrostatic Pressure N/m^2 (kg/cm^2)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

*Calibration data furnished by the manufacturer.

Explanations for columns including analysis:

Col 3 Total resistance of cell as measured in the field. With a 4-conductor cable the cell resistance is measured directly, and this column may be left blank.

Col 4 Resistance of the white and black conductors, as measured directly during the splicing operation. As an alternative a reasonably accurate value may be determined by subtracting the total resistance of the contraction and expansion coils measured in series from the sum of the resistances of the contraction and expansion coils measured separately.

Col 5 Resistance of cell excluding cable leads. It is obtained by subtracting col 4 from col 3.

Col 6 Temperature of the cell, obtained by subtracting (B) from the cell resistance in col 5, multiplying the difference by (C) and adding the product to (A).

Col 7 The resistance ratio of the cell as measured with the test set.

Col 8 Total change in resistance ratio (col 7) from a selected initial value, usually the first reading after the concrete/masonry has hardened or at about 24 h age. Proper algebraic sign should be shown.

Col 9 Multiply values in col 8 by the corrected calibration constant (D). Negative values of the ratio changes (col 8) indicate positive pore pressures. Except for minor ratio variation prior to the development of significant pore pressures, the cell will not respond reliably to negative pressures, and all entries in col 9 will represent pore pressures above the oil pressure in the cell chamber which will be approximately atmospheric.

NOTE — No temperature corrections are made; but the temperature data obtained is of general interest and provide a possible means for detecting faulty operation of strain measuring units installed in the vicinity of the pore pressure cells.

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