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कंकरीट बाँधों में विद्युत विकृति मापी युक्तियों का
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Indian Standard

**INSTALLATION, MAINTENANCE AND
OBSERVATIONS OF ELECTRICAL STRAIN
MEASURING DEVICES IN CONCRETE DAMS —
CODE OF PRACTICE**

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NEW DELHI 110002

FOREWORD

This Indian Standard 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.

The device developed for recording stress directly, is not capable of recording tensile stresses. Besides, it is very expensive and requires much more care for installation than that required for strain measuring instruments. For this reason measurement of strain in the dam is considered important.

Strain measuring device, when embedded in the concrete dam determines actual accumulated length changes at the point of instrument location due to changes in volume of mass concrete, namely, those resulting from applied loads and due to several other causes such as creep, temperature change, moisture change and chemical action of concrete.

It is necessary to sort out those parts of changes in length which are not attributed directly to stress developments in the mass concrete. These parts are due to : (a) volume changes due to changes in moisture content, (b) thermal expansion, and (c) autogenous growth. For large mass of concrete, it has been observed that moisture change is inconsequential and in most cases may be neglected in the stress-strain computations.

The effect of temperature on the volume change of concrete through thermal expansion shall also be considered. To compute this effect, a laboratory determination of the coefficient of thermal expansion of the concrete of the dam containing the embedded instruments is made.

The volume change due to autogenous growth characteristics vary depending on the type of cement used and the materials used in making the concrete. The growth may produce an increase or a decrease in volume during the process of hydration.

With a view to determining strain due to all causes other than stress, a 'no-stress' strain meter exposed to the same conditions as those of the surrounding concrete close to the strain meter is installed.

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 ELECTRICAL STRAIN MEASURING DEVICES IN CONCRETE DAMS — CODE OF PRACTICE

1 SCOPE

This standard covers the details of installation, maintenance and observation of electrical type strain measuring device suitable for embedment in concrete dams.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 STRAIN MEASURING INSTRUMENTS

3.1 For measuring strain in the body of the concrete normal gauge length strainmeter is used. However, with a view to average out discontinuities and heterogeneity inherent in a masonry dam, long gauge strainmeter is used for measuring strain in a masonry dam.

a) *Unbonded Resistance Type*

These instruments utilize the principle of change in electrical resistance of a elastic wire due to change in tension which is caused by strains in the surrounding concrete.

b) *Vibrating Wire Type*

These instruments work on the principle that the frequency of the vibrating wire depends on the tension in the wire caused due to the strain in the surrounding concrete.

3.1.1 *Description of Normal Gauge Unbonded Resistance Type Strainmeter*

The strainmeter is in the form of a long cylinder with flanges on each end to anchor the ends of the meter to the surrounding concrete. Its construction details are shown in Fig. 1. White cotton cloth is wound around the cylindrical portion which is corrugated in order to allow deformation. The cotton cloth is taped so that when the instrument is embedded in concrete the strainmeter allows only its flange ends to make a contact or bond with the surrounding concrete. Within a flexible brass cover is a steel framework on which are supported procelian spools around which are wound, under sufficient initial tension, two equal coils of fine steel music wire having resistance R_A and R_B . When the ends of the meter are pulled apart by expansion, the outer or expansion coil elongates and increases in tension and resistance. At the same time inner or contraction coil decreases in tension and resistance as it shortens. Changes in the ratio of the resistance of the outer (expansion) coil to the inner (contraction) coils used as a sensitive measure of length change in the strainmeter. The change in ratio of 0.01 percent normally indicates a change in length of about 4 millionth of centimetre per centimetre. Resistance ratio change are not affected by simultaneous changes due to temperature of the wires since temperature change affects both coils by an equal amount.

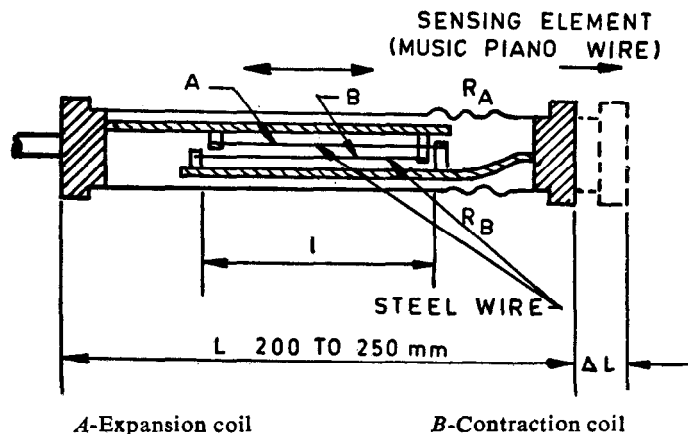


FIG. 1 STRAINMETER CONSTRUCTION

Dimensions of 'No stress' strainmeter metal container	A	B	C	D	E	t_1	t_2
	600	550	400	300	200	0.5	1.5

Temperature can be measured by determining the series resistance of the two coils. This is not materially effected by changes in resistance of the coil due to length change because these changes are substantially equal and opposite.

The range of strainmeters, while ample for measuring the deformations usually found in concrete, is definitely limited and strainmeters usually break if a crack develops across them. The usual allowable range of movement either way from the neutral point at which they are installed, is of the order of 0.001 cm/cm of strainmeter length.

Every strainmeter is supplied with calibration data sheet showing total resistance of both coils, individual resistance of expansion and contraction coils measured at 0°C and temperature constant for every change of 1 ohm in the total resistance of both the coils.

The entire length change represents the actual length change provided there is no change in temperature. If there is a temperature change the indicated length change must be corrected for thermal expansion or contraction of the meter frame in accordance with the instruction of manufacturer. The meters are usually furnished with about 75 cm of rubber covered 3 conductor colour coded cable attached. One of the conductor (green in colour) is made common to both coil, the white conductor connects to the other end of expansion coil and black conductor to the other end of contraction coil from so called neutral (or initial) position of meter about 2/3 and the range in expansion about 1/3 of the total. The readings are taken by a suitable readout arrangement which is basically wheatstone bridge.

3.1.2 Description of Vibrating Wire Type Strainmeter

This type of strainmeter is also in the form of a long cylinder with flanges in each end to anchor the ends of the meter to the surrounding concrete. The construction details of this type of meter are shown in Fig. 2. The prestressed vibrating wire is stretched between the two end

flanges of the transducer in such a manner that the natural frequency of vibration of the wire is a function of the change in the distance between the flanges. The flanges, when embedded in a concrete structure, will follow the strain in the concrete; consequently, the square of the gauge wire frequency will be proportional to the strain in the concrete. A single gauge may be used or several gauges may be combined to form a variety of rosette configurations.

3.1.3 Gauge length varies according to the use. Standard gauge have an overall length of 200-250 mm. The range of strainmeters, while ample for measuring the deformations usually found in concrete, is definitely limited and strainmeters usually break if a crack develops across them. The usual allowable range of movement either way from the neutral point at which they are installed, is of the order of 0.001 cm/cm of strainmeter length. Normal readout equipment which gives an accuracy of $\pm 2 \times 10^{-6}$ strain is suitable.

4 NUMBER, LOCATION AND LAYOUT

4.1 The number, location and layout depends on the type of information required. In general, information sought relates to the following:

- a) Distribution of stresses at a point in a massive structure,
- b) Stresses near the surfaces which are affected by temperature variation, and
- c) Stresses in special foundation features.

4.2 Measurement of Stresses from the Strains at a Point in a Massive Structure

4.2.1 To determine the stress at a particular point in a massive structure several choices of the layout for strainmeter groups are available depending upon the overall behaviour of the structure:

- a) A group of five strainmeters oriented as shown in the Fig. 3 with one 'no stress' strainmeter may be used for the locations where the behaviour of the structure is

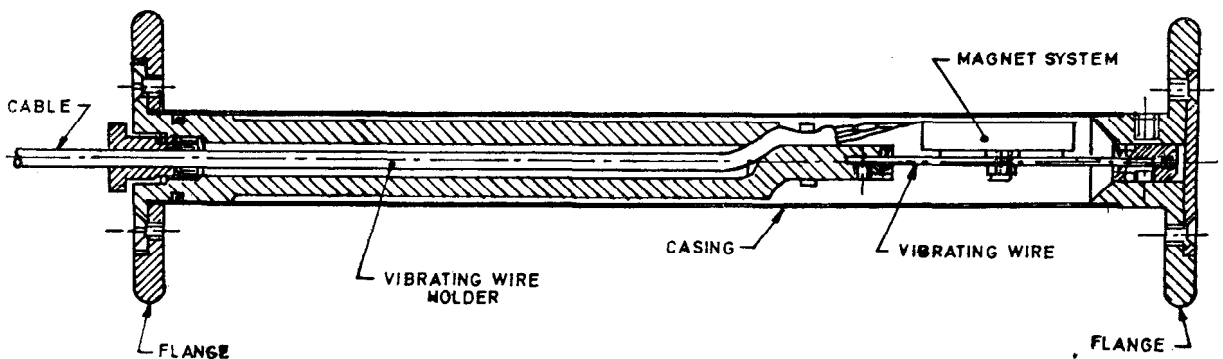
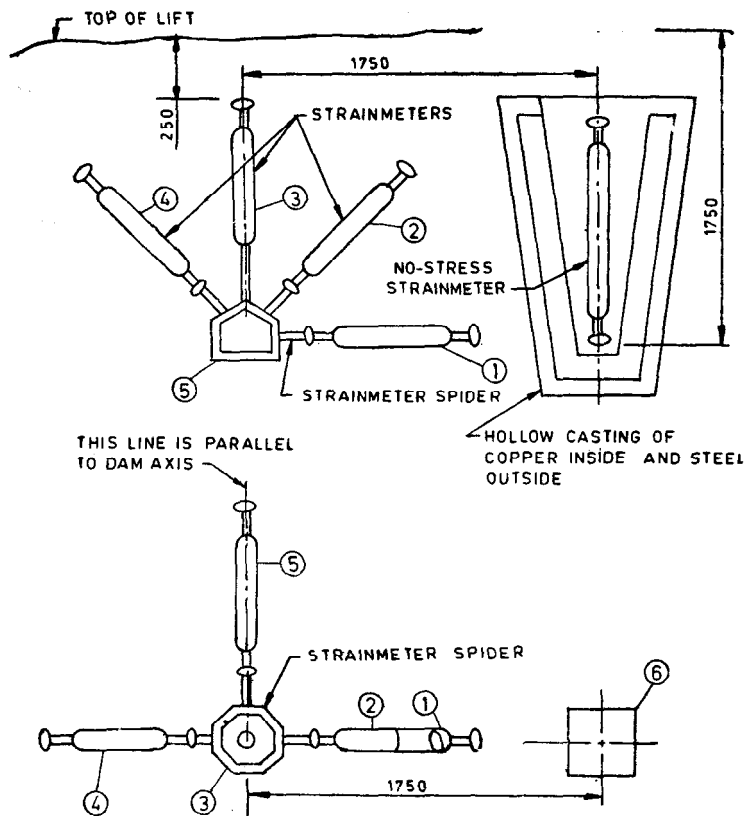


FIG. 2 STRAIN GUAGE, VIBRATING WIRE



All dimensions in millimetres.

FIG. 3 TYPICAL LAYOUT FOR A GROUP OF FIVE STRAINMETERS

likely to be predominantly two-dimensional in nature. This type of behaviour may be visualised for concrete/masonry dam blocks resting on nearly horizontal foundations and having no large sized openings in the near vicinity of the location of strainmeter group. This arrangement is suitable for majority of the dams in the country where contraction joints between the blocks are not grouted and the overall layout specifies stipulation as above.

- b) In case of locations where the behaviour of the structure is likely to be predominantly three-dimensional in nature, six components of strains in different directions are required to be measured to determine the state of strain/stress at a point. For this purpose a group of nine strainmeters is recommended. The arrangement of individual strainmeters in such a group is given as below :

- Meter No. 1 — Horizontal, parallel to the axis of dam.
 Meter No. 2 — Horizontal but perpendicular to the axis.
 Meter No. 3 — Vertical
 Meter No. 4 — Vertical plane perpendicular to the axis. Similar to hour hand of clock at 4:30 o'clock when looking towards right abutment.

Meter No. 5 — Also in vertical plane perpendicular to the axis, perpendicular to No. 4 (hour hand at 1'30).

Meter No. 6 — Vertical plane parallel to the axis, similar to 1'30 o'clock when looking downstream.

Meter No. 7 — Vertical plane parallel to the axis and perpendicular to No. 6 (hour hand at 4'30).

Meter No. 8 — Horizontal plane, similar to 1'30 o'clock if 12'00 is upstream.

Meter No. 9 — Also in horizontal plane, perpendicular to No. 8 and at 4'30 o'clock if 12'00 is upstream.

In addition a 'no stress' strainmeter should be installed by the side of the group of 9 strainmeters described above.

4.2.2 The strainmeter groups are generally located at an equal spacing along a horizontal line across the section of the dam as shown in Fig. 4. The lowest strainmeter group near the foundation of the dam should be located sufficiently away from the foundation grade so that the local disturbances in the stress fully produced by the irregularities in the foundation grade may be avoided. It is recommended that the lowest level of installation for the strainmeter

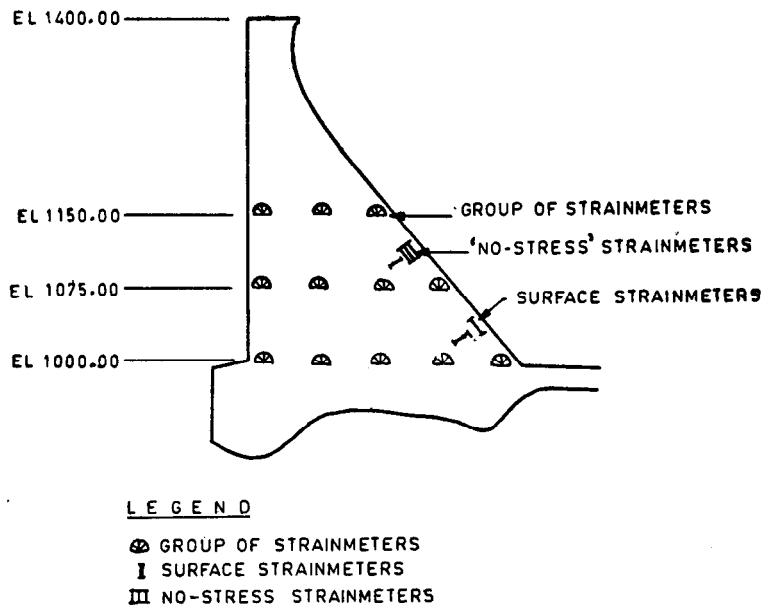


FIG. 4 TYPICAL LAYOUT OF STRAINMETERS IN CONCRETE/MASONRY DAM

groups should be kept at about 1.5 m away from the dam foundation interface. Similarly, the installations which are designed to measure overall stress field in the dam have to be kept at a minimum distance of 1.5 m, away from the boundaries of large sized openings which may be present in the section of the dam. As far as possible, the individual strainmeter groups should be located in the section in a single vertical plane.

The provisions made for the layout of strainmeters in IS 7436 (Part 2) : 1976, should be kept in view.

4.2.3 Outermost strainmeter groups should be placed at a minimum distance of one metre from the surface with a view to avoid influence of local effects on the surface.

5 METHODS OF INSTALLATION

5.1 The strainmeters although rugged in construction, need enough care in the field while these are placed in concrete with a view to ensuring accurate measurements.

5.2 Prior to the embedment of strainmeters, each instrument should be thoroughly checked. In case of unbounded resistance type strainmeters, meter resistance, lead resistance and resistance ratios must be checked and values recorded in the proforma given in Annex B. These observations should also be repeated after shifting the additional length of cells and recorded in the proforma.

In case of vibrating wire type strainmeters, zero frequency shall be checked and recorded. These readings should be repeated after splicing.

5.3 Embedding Procedure for Strainmeters

5.3.1 Separate Single Strainmeter

Single strainmeters are usually embedded near the top of a lift. The following is the embedding procedure :

- a) Dig into the area 1 m × 1 m for the depth up to 0.7 m. Discard all aggregates over 7 cm size. Backfill sufficiently and provide a bed for the instrument.
- b) Drill the hole with the help of electric laboratory vibrator and insert the strainmeter in the hole or lay flat for horizontal meter in correct direction.
- c) Vibrate around deeply embedded meters or hand puddle around shallow meters.
- d) Check angles, directions, and depth.
- e) Continue backfilling by hand with the same concrete as mass concrete, used in construction, after discarding aggregate above size, and hand puddle.
- f) A flag is put on the embedment location for easy identification.

5.3.2 Groups of Separate Strainmeters

All the steps, except Step (b) described in 5.3.1 above remain same. As a substitute for Step (b), the following procedure shall be adopted:

'Use an electric laboratory vibrator to make a hole for vertical and diagonal meters and insert meters in a hole or lay flat for horizontal meters in correct direction'.

5.3.3 Embedding Procedure for Larger Groups of Strainmeter Mounted on Spider

For a larger group of strainmeter up to a maximum of 9, more elaborate preparation must be made to ensure correct installation in the limited time available before the mass concrete attains initial set. With a view to simplify and save time, strainmeters are mounted on the spider.

Spider consists of a hub which has number of rods attached. The rods are screwed into the drilled holes in the hub and are threaded at one end to fit into the tapped hole in the end of the strainmeter. It facilitates embedment of a group of strainmeters at a location for eventual 2- or 3-dimensional stress analysis. The method described below may be followed.

A hole is drilled in a completed lift of concrete or formed at the time of concrete placement into which an anchor rod is installed by grouting. This anchor rod will have a threaded portion protruding above the concrete into which the spider having a threaded hole is screwed on. The strainmeters are attached to the legs of spider and the cables are taken to the contraction joint between blocks through a groove already formed in the previous lift and then covered with mortar. The above works are carried out a day prior to the placing of next lift of concrete. The strainmeter group is temporarily covered with a box which will be removed when the area around the group is ready for concreting. The group is covered with the same mass concrete but with aggregates above 2.54 cm removed and the concrete is carefully vibrated using a small pneumatic vibrator.

The above process helps to keep the strainmeters in proper alignment and gives better protection to the cables.

5.3.4 Embedding Procedure for Group of Surface Strainmeters

The positioning of the meters at the required distances from the face in a vertical plane and at the proper slope is achieved by providing special pipe brackets bolted or fastened to the top of the forms. Each bracket with a length of 38 mm pipe sealed at the bottom end, is held at the proper distance from face and kept parallel to the form surface. When the concrete is placed, each pipe forms a hole slightly larger than meter diameter. A shallow hole about

200 mm deep is dug around each pipe and after the concrete has stiffened slightly, the bracket screws are removed and the pipes pulled out and meters placed in holes. The space between meter case and sides and bottom of hole is filled with mortar and carefully tamped to ensure complete contact with the instrument. A barrier shall be erected to protect the area when the concrete gets hardened.

5.3.5 Embedding Procedure for Strainmeters Near Foundation Profile

Strainmeter groups may be embedded in the desired location. Embedding procedure as described in para 5.3.1 and 5.3.2 shall be followed as applicable.

5.4 'No-Stress' Strainmeter

With a view to determining the corrections to be applied on account of autogenous growth and thermal expansion of mass concrete, 'no-stress' strainmeters are installed by the side of both normal and long gauge group of strainmeters. These are embedded in metal containers.

Metal containers maintain continuity of the prism concrete in which 'no-stress' strainmeter is embedded with the mass concrete, while ensuring same temperature and humidity which is considered as positive necessity.

5.4.1 Embedding Procedure of 'No-Stress' Strainmeter Using Metal Container

The dimensions of the container are furnished in Fig. 5. Embedding procedure is as follows:

- The bimetallic container, made of steel and copper, is anchored against the previous concrete by stay wires not to be lifted up during concreting.
- Place mass concrete around up to 250 mm from the top of container.
- Fill mass concrete of same constituents and grade in the container up to half of its depth. Insert a strainmeter in the container checking the right position and direction and then fill the remaining half with concrete.
- Place mass concrete to the required height.

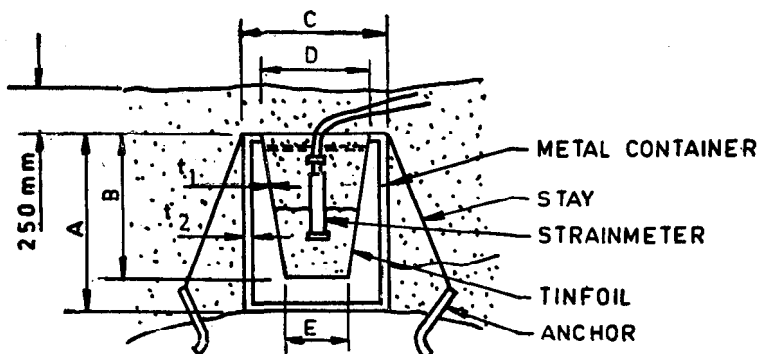


FIG. 5 'NO-STRESS' STRAINMETER INSTALLATION DETAILS

6 CABLES AND CONDUITS

6.1 The splicing and protection of cables shall satisfy the requirements as laid down in IS 10334 : 1982 for unbounded resistance type strainmeters.

6.2 Provision of additional 10% or 1.5 metres (whichever is more) for the estimated length of cable shall be made.

6.3 Strainmeters and 'No-Stress' strainmeters shall be properly designated for clear identification. After splicing a copper band with the instrument identification number stamped or punched on it, it is crimped to the cable about 1 m from the meter end and a similar band crimped 0.3 m from the free end of the cable. Further toward off possibility of copper band being stripped off during placement operation, a second marker consisting of identification number marked on white tape and covered with linen and friction tape should be placed around the cable near the reading end.

6.4 Provisions contained in 4.3.1 of IS 6524 : 1972 shall also apply to the strainmeter installation.

7 TERMINAL BOARDS

7.1 All the cables shall be terminated in a suitable terminal board.

8 OBSERVATIONS

8.1 Observations of the resistance ratio and resistance of the strainmeter are made by connecting the meter conductors, until these are soldered to the terminal contacts on terminal boards, to the binding posts of the standard. Wheatstone bridge in the order specified by the manufacturer. Subsequent to their terminations on the terminals boards in galleries, observations of meters are made by connecting the required cluster of contacts to the test set with the help of female plug which has socket at one end and individual conductors equipped with metallic like terminals for connection to the test set binding posts at the other end. Care should be taken to connect the cable leads in the order specified by the manufacturer to ensure correct measurements.

8.2 Note the zero frequency of the gauge before installation. The variation, if any, for the zero frequency recorded in the calibration data provided with the gauge could be due to difference in the temperature from the calibration temperature.

During and after the installation of the strain gauge in concrete, regular readings shall be taken and recorded. A reading is taken after the concrete is set and it shall be recorded as initial reading.

8.3 Reading Schedule

The following reading schedule shall be adopted:

a) During Installation

- i) One reading prior to embedment.
- ii) One reading when meter is about half embedded.
- iii) One reading when the meter is fully embedded.
- iv) One reading when the cable is being laid out.
- v) One reading when cable is taken to terminal board.

b) During Construction Period of Dam

<i>Time after Installation</i>	<i>Frequency of Reading</i>
Zero day	Two readings per day, spaced at least 6 h
1st to 14th day,	Once a day
3rd to 6th week,	Twice a week
7th week to completion of dam	Once a week

c) During commissioning and subsequently for every 1.5 to 3.0 m change in the reservoir levels.

8.4 Forms of Record

Observations shall be recorded on a suitably designed printed field reading form. These forms should be got printed sufficiently in advance and kept ready. Duplicate copy of the observations should be prepared simultaneously. The original should be sent to the Design Office or to the office entrusted with the analysis of data and duplicate retained in the field record office for future reference.

9 SOURCES OF ERRORS

- a) Presence of moisture inside terminal panel in case of unbounded strain gauge type.
- b) Loose circuit connections of the test set.
- c) Faulty cable leads.
- d) Imperfect cable splice.
- e) Presence of deposit on cluster of contacts.
- f) Low voltage of batteries.

10 COLLECTION OF COMPLEMENTARY DATA

The following properties of the dam concrete shall be defined:

- a) Modulus of elasticity at various ages.
- b) Poisson's ratio.
- c) Creep properties at various ages.
- d) Coefficient of thermal expansion.
- e) Autogenous growth.
- f) Thermal diffusivity.

11 METHOD OF ANALYSIS

11.1 Computation of Length Change and Strain

11.1.1 Correction to Calibration Constant for Unbounded Resistance Type Strainmeters

Sample data sheet on which temperatures, length changes and strains of field readings are computed is shown in Annex C.

Calibration constant supplied by the manufacturer shall be corrected by the following formula:

$$C' = C + \frac{Y_c (0.89)}{R}$$

where

C' = the new calibration constant,

C = the original calibration constant,

Y_c = the resistance of a pair of conductor cables, and

R = the meter resistance at 0°F.

Therefore, when the strainmeter is embedded in concrete which expands freely due to a temperature rise, the strainmeter is likely to indicate a contraction. Thus, certain definite corrections (addition for increase in temperature and (*vice versa*) as may be prescribed by the manufacturer for change of every centigrade in temperature must be applied to the indicated length change shown in col 9 of the computation sheet Annex C.

11.1.2 Correction to Calibration Constant for Vibrating Wire Type Strainmeter

No corrections need be applied to calibration

constants in case of vibrating wire type strainmeters, since in this case the calibration constants are not affected due to temperature changes.

11.1.3 A single reading of the strainmeter has no meaning but the difference between the two readings indicate the length change occurring from the time of first reading to the time of second reading.

11.2 Computation of Elastic Strains from Length Changes of Strainmeter

Since the main purpose is to evaluate stresses it is necessary to subtract this portion of length change which is due to causes other than stress. With a view to estimating the elastic strains, generally following corrections are carried out in addition to corrections for meter expansion:

- a) Correction due to thermal expansion of the concrete.
- b) Correction due to autogenous growth.
- c) Dilatation correction.
- d) Poisson's ratio correction.

In limited installations, correction for thermal expansion of concrete may only be made. However, in important structure, all the above corrections may be made with a view to increasing the reliability of results. For limited installations procedure for computation of strain as given in Annex C shall be followed.

ANNEX A (Clause 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	Title	IS No.	Title
6524 : 1972	Code of practice for installation and observation of instruments for temperature measurement inside dams : Resistance type thermometers		connecting resistance type measuring devices in concrete and masonry dams
10334 : 1982	Code of practice for selection, splicing installation and providing protection to the open ends of cables used for	10434 (Part 1) : 1982	Guidelines for installation, maintenance and observation of deformation measuring devices in concrete and masonry dams : Part I Resistances type jointmeters

ANNEX B
(Clause 5.2)

PRE-EMBEDMENT TESTS

B-1 RESISTANCE TYPE STRAINMETERS

Project Instruments
Air temperature Manufacturer's No.
Wet bulb temperature Project No.
Location

- c) Green-black
- d) White

B-1.1 Resistance Before Cable Splicing

- a) White-black
- b) White-green
- c) Green-black
- d) Resistance of one pair

B-1.2 Ratio Instrument Only

- a) Direct ratio (white-green-black)
- b) Reverse ratio (black-green-white)

B-1.3 Individual Conductor Resistance

- a) Length
- b) Black

B-1.4 Resistance of Instrument After Cable Splicing

- a) White-black
- b) White-green
- c) Green
- d) Resistance of one pair

B-1.5 Ratio Instrument with Cable

- a) Direct ratio (white-green-black)
 - b) Reverse ratio (black-green-white)
- Date of test :

Date of embedment :

Name and signature of observer

NOTES :

ANNEX C
(Clauses 11.1.1 and 11.2)

STRAINMETER DATA SHEET

Manufacturer's No.....Strainmeter No.
Location.....Block.....Chainage..... Sta.....El.....

Calibrations

Meter resistance of 0°Fohms
Change in temperature per ohm change in resistant..... °F
Useful rangeratio in percent
Original calibration constantmillionths per 0.01 percent ratio change
Calibration constant corrected for leadsmillionths per percent 0.01 ratio change
Resistance of leads at 70°Fohms (pair)
Temperature correctionmillionths per..... °F

Contraction Expansion

1	2	3	4	5	6	7	8	9	10	11
Date	Time	Observed Resistance	Change in Resistance	Indicated Temperature °F	Resistance, Percent	Change in Ratio, Percent	Indicated Unit Length Change, Millionths	Correction for Meter Expansion, Millionths	Actual Length Change Millionths	Remarks

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