IS 14248 (1995): Guidelines for instrumentation of barrages, weirs [WRD 16: Hydraulic Structures Instrumentation]

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IS 14248 : 1995
(Reaffirmed 2005)

भारतीय मानक

बैरेजों और वियरों के उपकरणीकरण के मार्गदर्शी सिद्धान्त

Indian Standard

GUIDELINES FOR INSTRUMENTATION OF BARRAGES AND WEIRS

UDC 626·82·05

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 1995

Price Group 4

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.

In order to measure various parameters, so as to monitor the stability of barrages instrumentation is necessary. This draft standard covers the guidelines based on the practices being followed at present and the use of some of instruments.

Indian Standard

GUIDELINES FOR INSTRUMENTATION OF BARRAGES AND WEIRS

1 SCOPE

This standard covers the choice, description, installation, observation and maintenance of instruments installed in Barrages and Weirs for measuring the uplift pressure below the structure, relative displacements of the structural units, the foundation pressure and the stresses in the concrete and reinforcements.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
6532 : 1972	Code of practice for design, installation, observation and maintenance of uplift pressure pipes for hydraulic structures on permeable foundations
7436 (Part II) : 1976	Guide for types of measurements for structures in river valley projects and criteria for choice and location of measuring instruments: Part 2 Concrete and masonry dams
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
13232 : 1992	Code of practice for installation, maintenance and observation of electrical strain measuring devices in concrete dams

3 TYPES OF MEASUREMENTS REQUIRED

3.1 Measurement of Water Levels on the Up-stream and Downstream of Barrage Bays

This measurement is useful for calculating the discharges passing over the barrage and for comparing the hydraulic jump condition theoretically expected with the jump behaviour actually observed. Measurement of water levels on the upstream of the barrage beyond the drawdown effect as well as on the downstream beyond the stilling basin need to be measured for correct computation. A measurement of water surface profile on either side of the divide wall on left and right side be made to assess the hydraulic jump conditions.

3.2 Measurement of Uplift Pressure

This measurement is necessary:

a) to determine the actual uplift pressures occurring below the floor at different points and to locate the zones where the pressure is exceeding the safe balancing weight of the structure,

b) to locate if any piping phenomenon is occurring anywhere below the floor,

c) to ensure that the hydraulic gradient of the sub-soil seepage flow is safe towards the end of the floor, so as not to exceed the safe exit gradient at the tail end of the barrage, and

d) to compare the theoretically computed uplift pressures with those actually observed.

3.3 Measurement of Stress and Strain in Concrete, Reinforcement and in Foundation Soil

If the barrage floor is a relatively thin reinforced concrete raft constructed over alluvium, it is very difficult to calculate the exact stresses expected to develop in the raft concrete and the reinforcements. Theoretical calculations are generally done with simplified assumptions. It is, therefore, necessary to know the actual stress and strain developing in the raft, at least at the vulnerable locations. This can be done by embedding strainmeters on the surface of the reinforcement of the barrage raft or directly in concrete.

It is also sometimes necessary to know the soil pressures under the barrage floor, piers or abutments particularly when the foundation is soft, weak or when differential settlement is apprehended.

3.4 Measurement of Displacements

3.4.1 *Displacement of the Main Barrage Structure*

It is sometimes observed that the adjacent units of the barrage structure separated by construc-

tion joints undergo relative vertical displacements, resulting in breaking up of the copper seals at the joints. This is more common at the abutment toe, where it is normally separated by expansion joints from the first or the last bay of the barrage raft. Such displacement happens at the joints in the other bays of the raft as well. Once the seal is damaged, considerable seepage can take place through the joint, resulting in reduction of the pond level. To take early precautions against any damage to the joint seals, relative displacements need to be monitored at the vulnerable joints.

3.4.2 *Displacement of the Flexible Protection Blocks*

Flexible cement concrete blocks are constructed, cast-in-situ, just upstream and downstream of the pucca floor of the barrage or weir. Although these cement concrete blocks are normally meant to launch in case of scour in the river bed, but the set of blocks immediately downstream of the pucca floor are not supposed to undergo any displacement as these are to release the uplift pressure at the exit end and at the same time prevent any scour or piping. However, in major barrages in alluvium, occasionally displacements have been noticed of these cement concrete blocks as well. This can never be seen when the hydraulic jump is actually forming over the stilling basin. As a result, considerable damage can happen to these blocks unnoticed under water. It is, therefore, desirable to monitor the displacements of these cement concrete blocks, at least in some representative bays, by installing automatic checking devices fitted to these blocks. The measurement of displacement of the concrete blocks provided immediately upstream of concrete floor would be necessary.

3.5 Measurement of Tilt

The abutment blocks, wing walls, divide walls, etc, are tall isolated structures that may undergo tilt, with or without vertical or horizontal displacements, particularly in seismic regions or where deep scour and differential pressures are expected on these structures. Instruments like plump bobs or clinometers provided in observation niches in the body of the structures, can be used for monitoring the tilts.

3.6 Undershot Flow in Stilling Basins

Hydraulic jump is never fully efficient in the stilling basins, which are generally designed for one particular worst condition of flow. Therefore, under partial gate open conditions, shooting flow often occurs under the jump, causing severe vibratory suction over the flexible apron. This sometimes causes vertical displacement of downstream cement concrete blocks, which needs to be monitored.

4 OBLIGATORY AND OPTIONAL MEASUREMENTS

4.1 Obligatory Measurements

4.1.1 *Water Level Measurement*

This measurement is obligatory, particularly at the two ends of the barrage and weir, as also at some intermediate bays, both at the upstream and downstream of the barrage axis.

4.1.2 *Uplift Pressures*

This measurement is obligatory for gravity type floor of barrages and weirs. For reinforced concrete rafts also, in some representative bays, this measurement should be done, at least at a point just downstream of the main gate seal and also below the end of the pucca floor.

4.1.3 *Displacement*

Displacements should be measured at the joints between the toe of the abutments and the first and last barrage bay floor, unless the barrage floor is constructed directly on rocky river bed.

Relative displacements of cement concrete blocks should be monitored, for the blocks just downstream of the pucca floor, in barrages founded on loose river bed, subjected to rapid variation of hydraulic jump conditions.

4.2 Optional Measurements

The following measurements are optional and to be provided where vulnerability exists, say in highly seismic zones or in barrages constructed in relatively loose alluvium or clay:

(a) Tilt, (b) Stress, and (c) Strain.

5 CHOICE, DESCRIPTION AND LOCATION OF MEASURING INSTRUMENTS

General descriptions of the different instruments which are normally to be provided in barrages and weirs are given below.

5.1 Water Level Measurements

Automatic water level recorders should be fixed on the upstream and downstream sides of the abutment faces.

For intermediate piers and divide walls, painted gauges will normally do.

5.2 Uplift Pressures

The device for measuring uplift consists of vertical pipes with filter points installed at

predetermined locations just under the barrage/ weir floor, where the uplift pressures are to be measured. The readings are to be taken of the water levels in the standpipes, by means of a bell sounder.

The locations of the tapping points and details of the instrument normally used are described in IS 6532 : 1972. However, the number of tapping points can be considerably reduced in reinforced concrete raft type barrages. Similarly, it can be reduced in smaller barrages which are relatively less important.

For location of such pipes in R.C.C barrages *see* Fig. 1.

5.3 Stress in Concrete and Steel

The stress in concrete in barrage floors and piers can be indirectly found out, by measuring the strain in the reinforcement at vulnerable locations. Strain meters may be welded to one of the surface reinforcement bars at desired locations. It is to be ensured during the pouring of concrete that the strainmeters are not damaged or do not become out of action.

Strainmeters of both resistance and vibratory wire-type may also be directly embedded in concrete at desired locations. For this, reference may be made to IS 13232 : 1992. In barrage/weirs, single or two dimensional strain measurements are sufficient. Thermal expansion is also negligible as barrage raft is relatively thin as compared to mass concrete in dam.

Locations of embedding strainmeters in the barrage raft should be at the mid-bay and under the piers, where the stresses are normally maximum (*see* Fig. 2 and Fig. 3).

5.4 Stresses in Foundation

Soil stressmeters are provided at the foundation level, more often under the piers and under the abutment toe. There are two categories of instruments used for the purpose, namely contact pressure cells and total pressure cells. Stresses in the soil should be measured preferably under the crest and under the upstream floor (*see* Fig. 2 and Fig. 3). Electrical resistance or vibrating wire type instruments may be used for the purpose.

5.5 Displacement of the Different Units of the Barrage Structure

Relative displacements can be observed by installing jointmeters at vulnerable locations for example at the toe of the abutments, at the expansion joints in between the bays, etc. Two types of jointmeters are available, namely (a) resistance type, and (b) vibratory wire type.

Locations of the jointmeters should preferably be at place where the pressure on the raft is maximum, for example under the road bridge or gate bridge section.

At the abutment toe, preferably two such jointmeters may be provided, one under the gate bridge and one under the road bridge. At the other barrage bays, only one jointmeter is enough (*see* Fig. 4).

5.6 Displacement of Flexible Protection Blocks

A simple method can be used to monitor the vertical displacement of the cement concrete blocks if any, close to the barrage floor downstream. A continuous flexible (polyethylene) pipe may be inserted at the time of casting, through four or five cement concrete blocks

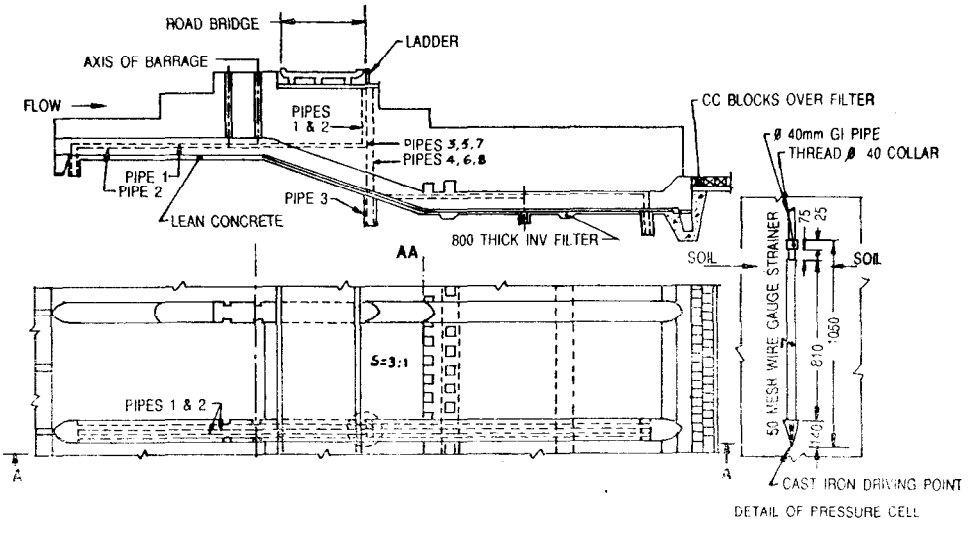

FIG. 1 TYPICAL LOCATION OF UPLIFT PRESSURE MEASURING DEVICE

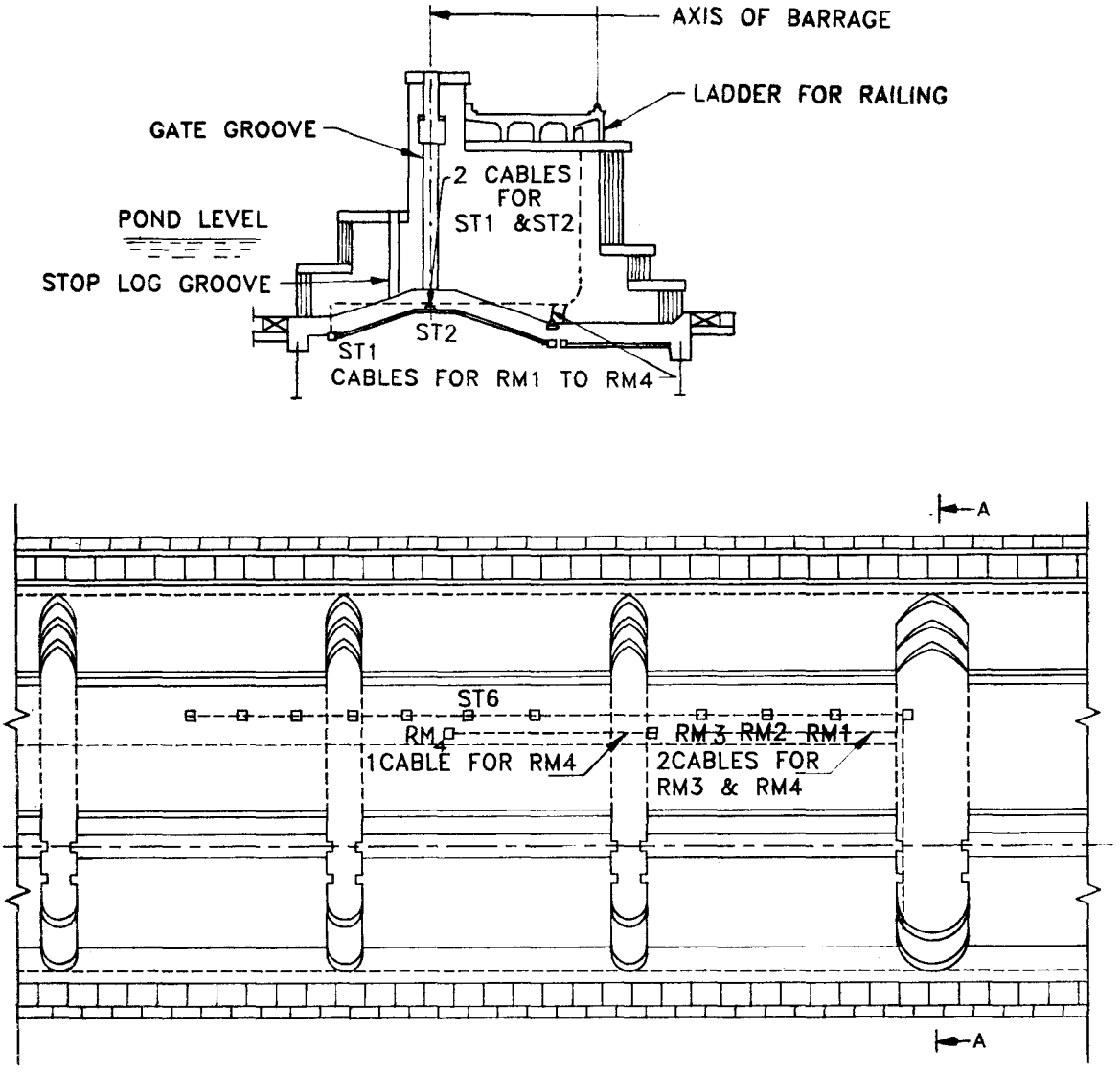

FIG. 2 TYPICAL DETAILS OF LOCATION OF INSTRUMENTS AND RECORDING POINTS OF REINFORCEMETER AND SOIL STRESS METER

in a row from the end of the barrage stilling basin, in front of a particular bay selected for this monitoring. A strong but flexible wire or chain is then passed through the flexible pipe (*see* Fig. 5). The tail end of the wire or chain is then firmly fixed by a nut and washer at the back of the last of the four or five cement concrete blocks to be monitored. The other end of the wire/chain is then passed through a pipe already embedded in the end-sill of the stilling basin, passed through the end sill and finally turned upwards through the adjacent pier and terminated in a small chamber on top, where it is passed round a pulley and kept balanced with the help of a counter-weight.

As and when these cement concrete blocks show the tendency to sink below the original level, tension develops on the wire/chain which is manifested by a vertical movement of the counterweight on the top of the pier. A certain extent of sinking of these blocks may be allowed, but precautionary steps may be taken, by operating the gates, if the sinking is appreciable. After the flow in the bay is stopped, the depth of sinking of the blocks are to be examined by probing from a boat and necessary repairs should be undertaken, by providing additional blocks of sufficient weight over the sunk ones or by providing boulders in wire crates upto the designed level. If the sinking of blocks takes the shape of a shallow bowl, it shows the tendency to form a natural pool, which may be beneficial in dissipating the excess energy passing down the stilling basin. Alternatively, the sinking can be measured

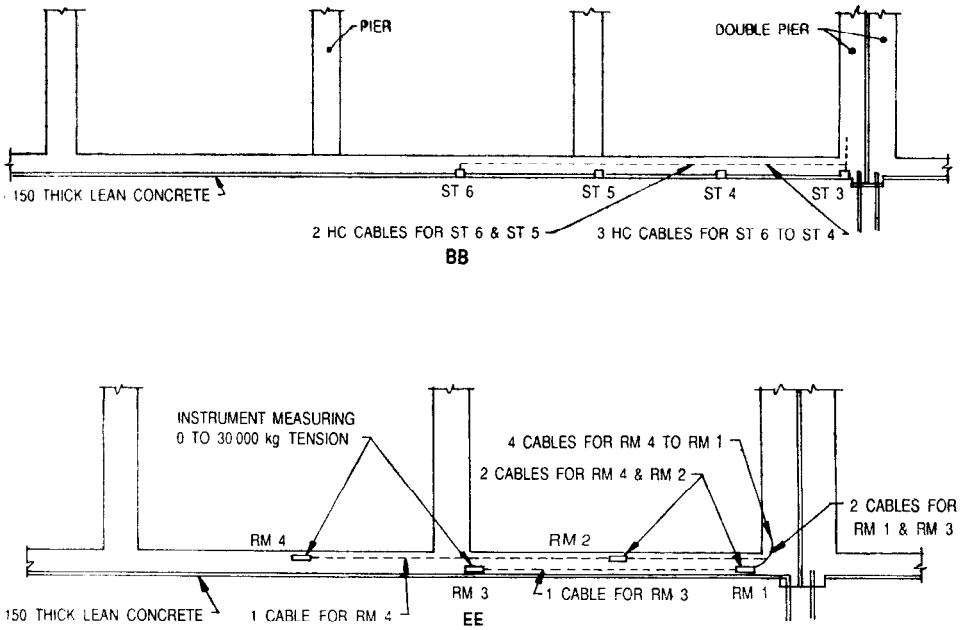

FIG. 3 LONGITUDINAL SECTION SHOWING LOCATION OF INSTRUMENTS AND RECORDING POINTS OF SOIL STRESS METERS AND REINFORCEMENT METERS

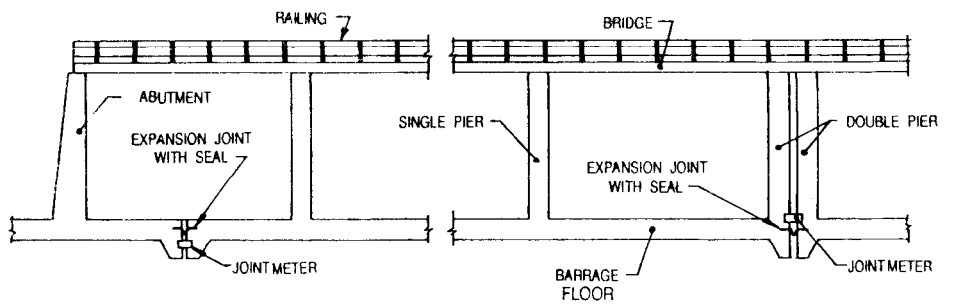

FIG. 4 LOCATION OF JOINT METER

taking soundings by approaching the location by a boat during lean period.

5.7 Measurement of Tilt

Measurement of tilt consists of measuring the change in angle of a reference axis with reference to horizontal or vertical planes. The observations are made in niches provided on the surface of the barrage abutments, wing walls or divide walls, protected by locked doors to prevent tampering. The simplest method is to provide hook for hanging the plumb bob in the roof of the niche. A cross mark is to be permanently embossed at the base, indicating the normal vertical position of the plumb bob. It is to be checked at least once a week, by suspending a plumb bob in each of these niches, which will give indications, if any tilt has occurred in these structures. Precautions should be taken, when a significant progress of the tilt is continuing.

In important barrages, clinometers may be properly fixed in the base of the niches and air bubble is centred with the help of a micrometer screw. The reading of the micrometer screw obtained at any particular time of observation, when referred to the initial reading, gives the value of tilt.

5.8 Undershot Flow Monitor

As already mentioned in **3.6**, it is often desirable to know, whether any strong shooting flow is passing underneath the hydraulic jump.

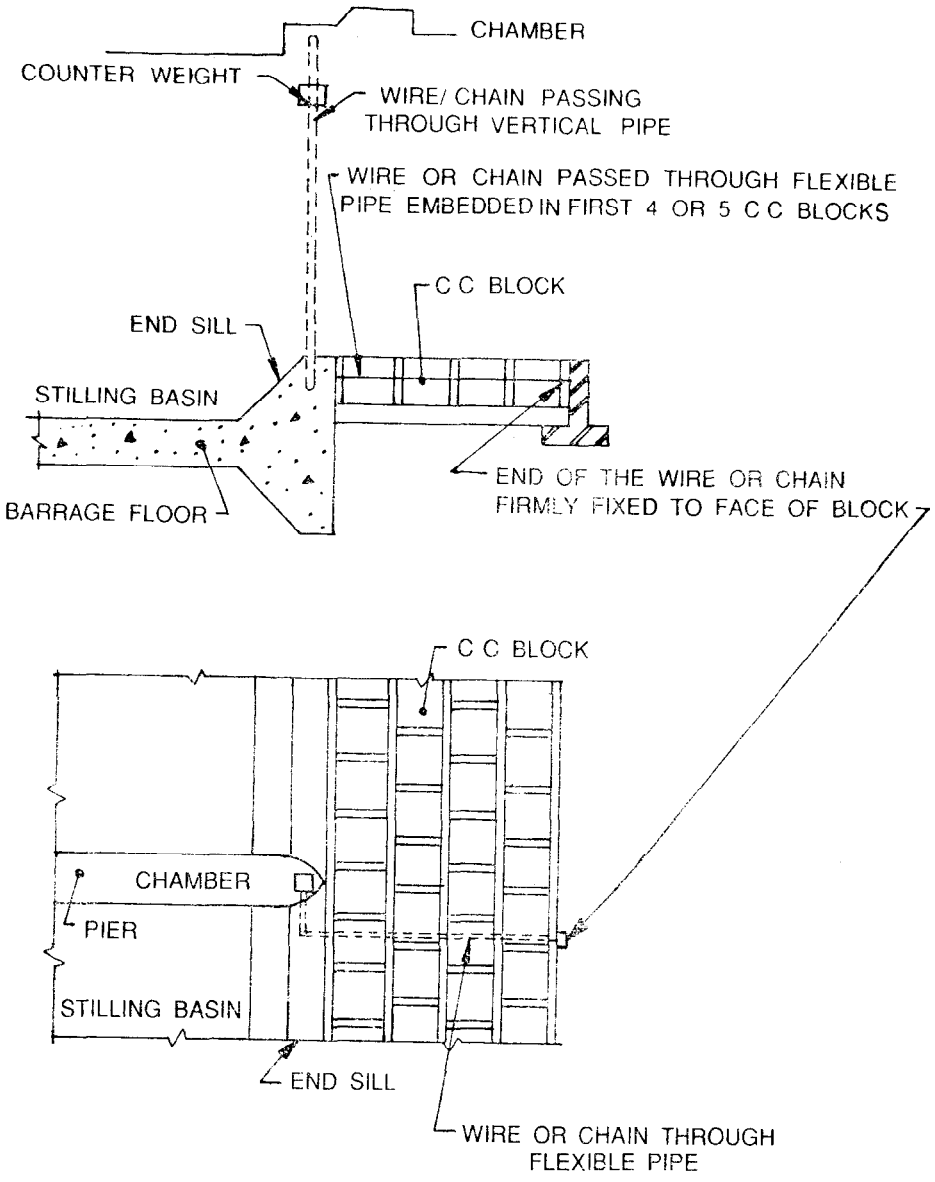

FIG. 5 FLEXIBLE BLOCK

The only method that can be adopted is by providing a pressure cell on the sloping face of the end sill of the stilling basin. The pressure cell has to be of considerable toughness, preferably having a metallic or neoprene rubber diaphragm on the exposed surface, which may not get damaged by any pebbles or gravels rolling along the bottom of the stilling basin and hitting the diaphragm like a jet.

The cell is to be connected by cables, passing through the end sill, to a tamper-proof terminal box fixed at the top of the adjacent pier (*see* Fig. 6).

As pressure cells are quite costly, one cell in the mid-bay of the undersluices and one cell in the central bay of the barrage portion are considered sufficient.

All these cells may be read regularly, whenever the barrage gates are partially operated and significant difference exists between the upstream and downstream water levels.

6 OBSERVATION AND MAINTENANCE OF THE INSTRUMENTS

Observation and maintenance record book for all the instruments should be kept by the technical head in charge of the barrage/weir operation. Routine and special observations are to be carefully recorded for each measurement and these are to be represented in chart form for quick understanding.

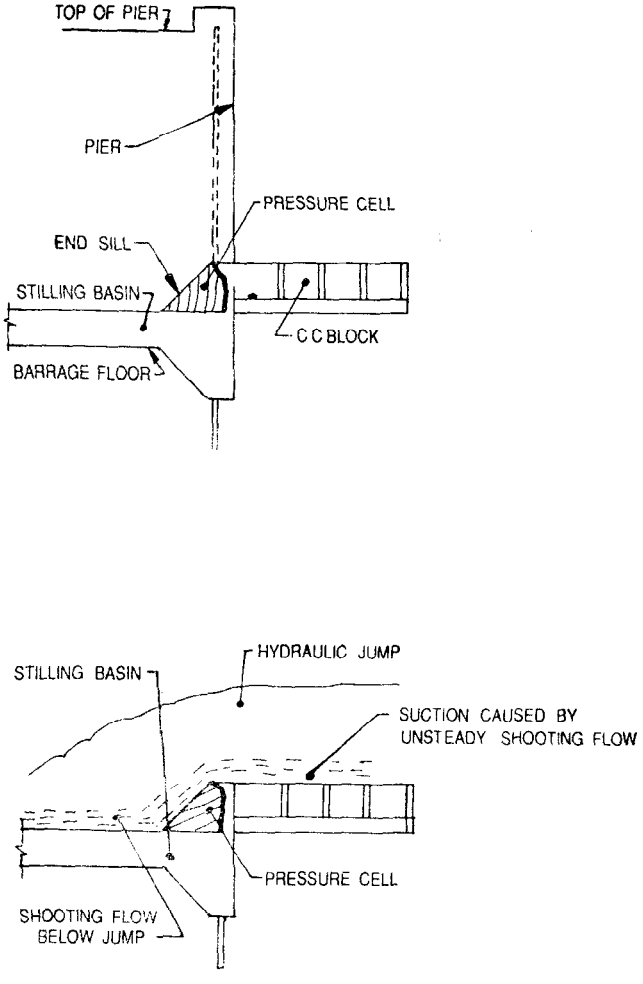

FIG. 6 UNDER SHOT FLOW MONITOR

The site officers often feel that there is no need to have meticulous observation and maintenance schedule for the instruments. But, it has been experienced in many barrages that careful observation of the instruments were neglected, resulting in considerable difficulty at the time of distress in understanding the problems and adopting correct remedial measures.

Thorough maintenance of connecting cables is very important. A chart is to be fitted at the control room, showing the relative locations and connections of the cable ends, with reference to the respective instruments which are embedded in concrete or in the foundation. A number of copies of such connection details has to be carefully preserved in the different offices connected with the barrage design and operation.

Pilferage of cables is very common. Therefore, all the cable ends must be protected inside tamper-proof concrete chambers/niches in the piers, abutments, wing walls, divide walls, etc.

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Review of Indian Standards

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.

This Indian Standard has been developed from Doc No. RVD 16 (87)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India