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SAFETY OF BARRAGE AND WEIR STRUCTURES — GUIDELINES

भारतीय मानक

बैरेज और वियर संरचनाओं की सुरक्षा — मार्गदर्शी सिद्धान्त

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 22 December 1989, after the draft finalized by the Barrages and Weirs Sectional Committee had been approved by the River Valley Projects Division Council.

The safety of barrage and weir structures should be ensured right from the investigation stage and continues up to the location, design, construction, operation and maintenance stages. There cannot be any laxity on these aspects. A safe structure should not only be hydraulically and structurally safe but it should also fulfil the functions for which it has been constructed. Fire fighting equipment may be provided near the barrages.

This edition 1.1 incorporates Amendment No. 1 (August 1991). Side bar indicates modification of the text as the result of incorporation of the amendment.

Indian Standard

SAFETY OF BARRAGE AND WEIR STRUCTURES — GUIDELINES

1 SCOPE

1.1 This standard provides guidelines on various aspects of safety of the barrage and weir structures, such as, investigations, location, design, construction, operation and maintenance.

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
6966 (Part 1) : 1989	Guidelines for hydraulic design of barrages and weirs: Part 1 Alluvial reaches (*first revision*)
7349 : 1989	Guidelines for operation and maintenance of barrages and weirs (*first revision*)
7720 : 1975	Criteria for investigation, planning and layout of barrages and weirs
8408 : 1976	Criteria for river training works for barrages and weirs in alluvium
11130 : 1984	Criteria for structural design of barrages and weirs
11150 : 1984	Code of practice for construction of concrete barrages

3 TERMINOLOGY

3.1 For various terms used in this standard, reference may be made to the following Indian Standards.

a) IS 6966 : 1989
b) IS 7349 : 1989
c) IS 7720 : 1975
d) IS 8408 : 1976
e) IS 11130 : 1984
f) IS 11150 : 1984

4 SAFETY ASPECTS ON INVESTIGATIONS

4.1 The investigations should be carried out without any laxity as the continued safety and efficient functioning of barrage/weir structure and integrating it with the master plan of the basin development depends on the data collected and analysed. The structure designed based on inadequate data may suffer an unexpected serious structural damage.

4.2 For details of preliminary and detailed investigations for barrages and weirs, IS 7720 : 1975 may be referred.

5 SAFETY ASPECTS ON LOCATION

5.1 For a safe and efficient barrage/weir, the location of the structure is very important. Various considerations for locating the structure at the proper place shall include the course of the river, the nature of silt, condition of the banks, width of the river bed, foundation conditions, confluence of tributaries, bends and rapids in the river, etc. The following aspects shall be thoroughly examined from safety considerations.

a) *Course of the River*

It shall be studied with survey maps/satellite imageries that the course of the river has not changed for many years at the prospective site of the structure. In the case of shifting rivers, proper measures shall be adopted to contain the river in the desired course.

b) *Nature of Silt*

It shall be examined to determine whether the soil through which the canal alignment runs, is able to withstand the velocity of flow which can carry the silt down the canal. This factor will influence the location of the head regulator and also the overall cost of the barrage as costly lining may be required otherwise for safe operation.

c) *Condition of the Banks*

It shall be ensured that the banks at the proposed location are firm and not easily erodible. The banks shall normally be high so that the country areas are not submerged during high floods. Otherwise, costly flood protective embankments would be necessary.

d) *Width of the River Bed*

The width of the river at the proposed location shall not be too wide which induces irregular silt forming shoals on the upstream and downstream and consequent irregular and likely cross flows. A very narrow width of the river shall also be avoided as it would reduce the waterway and induce high intensities of flow which would necessitate deeper cut offs and foundations and protective works to make the structure safe against surface flows.

e) *Foundation Conditions*

For the safety of the structure, the foundation conditions, such as, weak and fissured rocks, fault zones, clayey layer, silty layers prone to liquefaction, artisian and quicksand, etc, shall be thoroughly known so that proper foundation treatment could be effected.

f) *Confluence of Tributaries*

The location of the structure in the main river with a tributary flowing parallel and close to the main river shall be avoided as there would be possibilities at a later date of the main river breaking into the tributary and outflanking the structure thereby rendering it unsafe and infructuous.

g) *Corrective Measures*

It is always very difficult to select an ideal site for the location of a barrage and its head regulators satisfying all the requirements including the safety aspects. Hence, it often becomes necessary to select a site satisfying most of the requirements and for the rest, some corrective measures shall be incorporated in the layout and designs to ensure a safe structure. These include proper foundation treatment, properly designed guide bunds, spurs, flood protective embankments, pilot channels, silt excluding devices, proper gate regulation, etc.

6 SAFETY ASPECTS ON DESIGN

6.1 Parameters, such as, design flood, pond level, free board, waterway gauge-discharge curve, etc, shall be properly selected to ensure safe design of the structure and guidelines for the same are given in the following paras. Reference may also be made to IS 6966 (Part 1) : 1989.

a) *Design Flood*

The barrage/weir shall be designed to safely pass a flood with certain return period. Usually, in the case of barrages of minor and normal importance, the design flood for waterway shall be taken to have a frequency of 1 in 50 years. In such cases where risks and hazards are involved, a review of this criteria based on site conditions may be necessary.

b) *Free Board*

The free board shall be carefully fixed so that the structure and abutments are safe for a higher flood with a frequency of 1 in 500 years. The likely accretion of bed on the upstream should also be taken into account while fixing the free board. The top levels of abutments and piers shall also be fixed to accommodate the gates in the maximum lifted position such that these are not damaged by floating trees, etc.

c) *Afflux*

The permissible afflux shall be carefully fixed so that the waterways of the barrage can be fixed accordingly without causing damage to nearby important/populated towns, industries, etc and risk of outflanking by breaches of bunds, etc could be avoided. Occasionally, flooding of cultivated lands in the river bed islands and the banks, under extreme case of flood above 1 in 100 years frequency, may be allowed. Otherwise, the water-way will be unnecessarily too wide which may cause sluggish flow through the barrage, shoal formation, cross flows, excessive cost of structure, etc.

d) *Waterway*

The waterway of a barrage shall be very carefully fixed to avoid shoal formation and excessive scour.

e) *Hydraulic Design*

The failures of barrages/weirs can be attributed to the following main causes, acting alone or in combination. These are (1) undermining through piping, (2) eruption of floor caused by uplift exceeding gravity forces (not in the case of raft floor), (3) deep scour immediately upstream and/or downstream of the solid floor, (4) faulty construction, (5) faulty regulation of gates, and (6) excessive retrogression.

After proper investigation of foundation conditions of the proposed barrage and its abutments, suitable foundation treatments are to be proposed by the design organization for improving bearing capacity, reducing the settlement and avoiding liquefaction, etc. Proposals for preconsolidation, vibrofloatation, compaction piles, grouting of loose rock, ground anchors, etc, may be properly analysed and design intimated to the construction agency well in advance.

The hydraulic design of the barrage/weir shall be carried out to be safe against exit gradient, scour and uplift and settlement of foundation. For guidelines for their designs, reference may be made to IS 6966 : 1989. In general, this

would involve safe design of upstream and downstream cutoffs/sheet piles, energy dissipation arrangements, thickness of floor, flexible protections, etc.

f) *Structural Designs*

In so far as the structural design is concerned, the various forces and moments including those caused by the earthquake, differential heads, differential settlement etc, shall be taken into account and the various factors, such as, sliding, overturning, etc, shall be arrived at to be within the permissible limits. Allowable stresses in materials, such as, concrete, masonry, steel, etc, shall not be exceeded. For guidelines for structural design of barrage/weir, reference may be made to IS 11130 : 1984. Proper measures to protect the barrage crest and floor against abrasion damage by rolling boulders may be provided. Fenders may be added where navigation is expected.

Gate designs

For the safety of the barrages, proper remote control and group control systems of the gate operation must be provided. Sometimes, after the erection of the gates, some gate leaves vibrate under certain lifted conditions. These should be immediately checked by manufacturers and designers and necessary rectifications carried out.

Occasionally, floating tree trunks hit the underside of the gate leaves which may seriously damage the gates. Whenever such possibility exists, sufficient margin must be allowed above high flood level to allow large size tree trunks to pass underneath the gates.

Radial gates may be advantageous in barrages where flashy flood is expected. These can be operated in a shorter time than vertical gates.

g) *River Training Works*

Care shall be taken for the safe design of various river training works, such as, guide bunds, spurs, etc, and other safety works, namely, afflux bund, marginal and approach embankments, etc. For guidelines for design of river training works, reference may be made to IS 8408 : 1976. For major barrages, performance of river training works should be reviewed from time to time. If necessary, it may also be checked in models because the flow conditions in upstream and downstream regions of the barrages get considerably changed after a few years due to shoal formation, bank scour, etc. If necessary, the guide bunds are sometimes required to be extended or its protection works to be strengthened after the flood season. Detailed pictures of the flow conditions and their effect on river training works should be placed before the designers for review and reconsideration every year.

h) *Design of Other Components*

A safe design of fish pass would necessitate proper provisions for the safe passage of fish from upstream to downstream and *vice versa*. Effectiveness of the fish passes is to be regularly observed both during the monsoon and past-monsoon period. If it is not effective, proper modifications in the design and operation method have to be requested from the design organizations. Similarly, the safe design of navigation lock would necessitate proper filling and emptying arrangements, berthing arrangements, desilting arrangements, etc. Whenever ice formation takes place, provision of de-icing arrangements for proper gate operation should be ensured.

NOTE — For guidelines on the design of fish pass, navigation lock, trash racks or head regulator, etc, reference may be made to the Publication No. 179 Vol II* of the Central Board of Irrigation and Power, New Delhi.

7 SAFETY ASPECTS ON CONSTRUCTION

7.1 A good coordination between designing and constructing agencies shall be established for bringing out a safe and economical structure. The field engineers shall be in the knowledge of the implications of provisions in the design of various components. Any change required to be made on account of site conditions or any other reason whatsoever, shall not be attempted by him on his own without evaluating the implications due to such changes and the designer shall invariably be consulted to find out any other economical and safe alternative thereof. Frequent checks on the construction *vis-a-vis* design provisions and constant quality control shall be ensured for providing a safe structure.

7.2 For carrying out the construction efficiently and safely, the following points shall be carefully planned and data on the same regularly collected during the construction period:

a) Sequence of construction of various items of the structure including river diversion and de-watering arrangements.

b) Various constraints on different activities of construction of the components.

c) Inter-dependence of various items so that there is minimum interference in the continuity of progress.

*Manual on barrages and weirs on permeable foundation.

d) Obligatory precautions to be taken for the protection of season's works from the ensuring floods.

e) Special features, if any.

f) Proper lighting arrangements to be provided at the project site.

g) Right type and capacity of the equipment required for de-watering well point and pumping, excavation, machines, sheet piling equipment, foundation treatment, plants, such as, vibro-floatation, etc, compaction equipment, concreting plant, river crafts, floating cranes, etc to be carefully planned and arranged before the construction is started. Wrong selection of equipment often causes serious bottlenecks in construction and even causes accidents. The selection of the above may be got vetted in the design office including safety arrangements to be provided for their operation.

h) Safety crew including divers with full diving kit must be provided at site.

j) First aid kit for accident or emergency should be provided wherever necessary.

7.3 Right from the preparation of foundation for the structure, each and every component of the barrage/weir shall be constructed properly for ensuring safety of the structure. For general guidelines on the construction of barrages/ weirs, reference may be made to IS 11150 : 1984.

7.4 Safety aspects on the construction of following items shall be ensured by the site-in-charge as detailed.

a) *Foundation*

Foundation preparation is an important item since the whole structure is going to rest on the same. It shall be dressed up to the barrage/weir profile and excavation shall be carried out carefully without exceeding the tolerance limits. The foundation shall not contain loose pockets or materials and they shall be watered and compacted to the specified relative density. This is applicable to those portions of the foundation also which may become loose during excavation and de-watering operations. Clay pockets shall be treated as specified by the designer including removal, refilling with sand and compacting. It shall be ensured that proper drainage arrangements in the foundation in accordance with the design including inverted filter wherever indicated are provided before concreting work is taken up. To avoid honey-combing of concrete of the floor, proper mudmat of lean concrete usually 50 to 150 mm thick shall be provided.

b) *Cut-Off/Sheet Pile*

1) Wherever sheetpiles are to be provided, they shall be driven at their correct alignment without any gaps between them in the wall. Since it may not always be possible to drive them at exact plumb, suitable tolerances may be allowed. If the tolerances exceed the permissible limit, they shall be corrected by taper piles. If there is any split in the interlock, additional piles in front shall be driven to cover it. Driving of welded sheet piles of more than 8 m length shall not be allowed as the weld may give way due to excessive driving stresses. Random checking of sheet pile joints should be done for leakage by die-injection technique or any other suitable technique. Wherever seals are to be jointed to the sheet piles, it shall be carefully done by welding and bracing. Since sheet pile are designed to have hinge action at the top, it shall be ensured by the provision of the tar paper. Wherever two piles rows are provided side by side, cork mastic filler on top shall be provided to take care of uneven heights and hinge action.

   Sheet pile caping beams should be cast monalithic with the barrage raft. Otherwise clean cold joints may form at the inter face, which may cause short circuiting of the seepage flow and even piping along this joint.

   Vibrosinkers should be recommended for pile sinking to avoid mis-alignment, damage of pile head, separation of clutches and to facilities quick driving.

2) Wherever concrete/masonry cut offs are provided, precautions shall be taken to avoid cracking as it may lead to short circuiting of seepage path and the exit gradient may be exceeded endangering the safety.

c) *Solid Floor*

The solid floor shall be constructed carefully avoiding stratification of concrete which may lead to failure by blowing off against uplift pressures. Cold joints shall be avoided. The strength of cement concrete of the raft shall be maintained in accordance with the specifications so that the stresses in both the concrete and steel reinforcement are not exceeded. The main and distribution reinforcement of the raft shall be carefully laid in accordance with the specifications and design requirements. The spacings shall be arranged in such a way that proper placements of concrete and vibration are ensured. Reinforcement around sill beam grooves shall

not be omitted. Proper dowels between first and second stage concrete in the gate grooves, trestle foundation, etc, must not be forgotten. The pier reinforcement shall be properly anchored to the raft. Wherever horizontal or vertical construction joints are necessary, proper steps to cut the joint and provision of seals when the joint is to be left open for more than 3 days, are to be provided.

d) *Piers and Gates*

In the piers, correct alignment of the gate and stoplog grooves shall be ensured so that no difficulty is experienced in their operation, specially during floods. For inspection and repairs of the gate wheels wherever contemplated, suitable galleries in the piers with easy access shall be provided.

While concreting, the pressure relief pipes installed in the piers and their outlets shall not be lost sight of and the open ends of the pipes shall be covered so that the concrete does not fall into the pipes and chokes them.

In the case of gravity type of floor, the stepped pier footings shall be concreted up to the barrage floor level and further portion of the pier above the bay level shall be concreted simultaneously with the bay concrete. The steps shall be so provided that there is no vertical joint. In the raft type of floor, the bay concreting and pier concreting shall be done simultaneously.

e) *Abutment*

Anchorage of the abutment reinforcement to the base slab shall be ensured. The abutment well shall be raised simultaneously along with the backfill and in any case shall not be more than about 1.5 m above the compacted backfill. Specified relative density of the backfull shall be ensured by proper compaction. Wherever drainage is to be provided behind the abutment walls in accordance with the design, the same shall be done carefully so that the saturated water level of the backfill is not allowed to exceed the design values. Inverted filter and sealing arrangements at the junctions of different abutment blocks shall be properly ensured.

High abutments sometimes undergo long term settlements, in foundations susceptible to settlement, at the toe side resulting in gradual tilting of the abutment face. As a result, the gate grooves may get jammed. It may be desirable in such cases to provide extra depth for the vertical grooves on the face of the abutment to allow free movements of gates even if tilted.

f) *Divide Wall*

As the divide wall is the one coming under the direct attack of flood flow, proper protection around the same in accordance with the design shall be provided. The change in the levels of the bed in front of the sluice and spillway portion shall be gradually made up and abrupt changes avoided. The junction between the divide wall and the bay concrete shall be done with proper precautions.

Sometimes due to the cross-flow at the nose of the upstream divide wall, a differential scour may take place between the two faces of the divide wall. This may even cause tilting of the wall. Regular watch is necessary, by sounding, on the two sides of the upstream divide wall. If necessary, boulders in crates may have to be dumped near the nose if the scour is serious. Jute bags or nylon nets filled with sand may be dumped in deep scour holes and covered with crated boulders up to 1 m.

g) *Downstream Protection*

As the downstream inverted filter below the cement concrete (c.c.) blocks is very important as a measure against piping, it shall be laid with due care. The gaps between the c.c. blocks shall always be filled with small stones or bajri. Wherever downstream bed level is higher than the level of downstream c.c. block protection, reverse slopes, not steeper than 1 in 5 shall be provided and it shall be ensured that some loose stone protection is provided for a length of not less than 2 m in the higher bed portion after the reverse slope.

Sometimes, due to error in gate operation and also due to shoal formation near the barrage, high concentration of flow may generate unsteady shooting flow over the down stream protection works. To prevent any damage due to such contingency, indigenous geofilters of bamboo mattress, etc, can be provided below the mineral filters, to avoid displacement of the filter material from below the c.c. blocks resulting in the suction of bed materials underneath.

h) *Instrumentation*

The importance of instrumentation shall be understood fully and care shall be taken in their installation so that wrong data are not observed leading to misleading and dangerous conclusions. For guidelines on the instrumentation in barrages/weirs, reference may be made to IS 6532 : 1972.

It may be stressed that often the instruments are simply forgotten, once the construction is over. Even the locations of the instruments are not remembered. It is desirable to prepare an exhaustive manual for instruments embedded in the barrage, with their locations, frequency of observations, analysis to be done, importance of these observations, etc. This manual may be kept both in the offices of the Assistant

Engineers and Executive Engineers in charge of the barrage, as also in the site control room.

The location of each of the instrument may also be painted on the face of the piers where the end of the cable pairs emerge out. The actual tip location may also be indicated there by paints.

j) *River Training Works*

The materials used in the construction of various river training works, such as, guide bunds, afflux bunds, approach embankments groynes or spurs, etc, and that their construction itself shall be of required standards so that their failures, impairing the hydraulic performance and hence the safety of the diversion structure, do not occur, wherever filters are indicated in the design, they shall be provided without fail since the stability of the bunds would depend on it. It shall be ensured that the afflux bunds are tied to high grounds to prevent outflanking of the structure and endangering the same wherever the deep channel of the river hugs the guide bunds and adequate apron shall be provided to avoid scour and consequent failures.

k) *Head Regulator*

Head regulator is also a structure similar to the main structure in so far as the general principles of design are concerned. Hence, whatever precautions are to be observed in the construction of the main structure from safety point of view, they shall be followed for the head regulator also.

Whenever there is a chance of floating debris, such as, grass logs, tree trunks, etc, entering the canal through the head regulator, log-booms or trash booms may have to be provided at the upstream of the head regulator.

If heavy silt deposition takes place at the entry of the canal, thereby reducing the canal capacity, it may be necessary to have a small dredger operating in the canal (damage of lining in the canal should be provided) and clearing the silt deposited. The dredged material can be dumped on either side of the bank.

m) *Damages due to Rolling Stones*

Barrages/weirs located in the bouldery reaches face the problem of abrasion and damages due to rolling stones thus endangering the safety of the structure. In order to ensure the safety, measures like provision of richer concrete in the top thickness of the floor, paving stones, clading of pier nose with steel or stone, etc, shall be adopted.

While repairing the cavaties on the crest slope and cistern of the barrage and in the piers, proper dowel bars and wire mesh may be embedded inside the cavities before concrete is poured into it. At the surface, special concrete, namely, haematite concrete, epoxy concrete, etc, may be used, for a thickness of 150 mm or so.

When big boulders roll over the barrage, steel rails with welded anchors may be fixed on the surface, so that the boulders cannot damage the concrete surface.

n) *Shearing Off of Pier Reinforcement*

When the piers are under construction, the projecting pier reinforcement shall be properly protected from floods by bending them in the direction of flow, well before the floods and later on straightening them when the construction is resumed. As some damages could be caused due to oblique flow or any other reason, the reinforcement shall be first checked up before starting the construction after floods whether they are loosely sticking out or not. After ensuring its proper bending with the lower portion, new reinforcement shall be welded on to the old ones. Proper bonding of new concrete with the old one shall also be ensured. A few welded rods shall also be test checked for their strength.

p) Provision of thrust forces, exerted by ice-covers of the pond, with reference to the safety of the structure should be made. This provision is of importance in sub-Himalayan areas of the country.

Provision for safety against uplift forces on the floor structure that are exerted by the water seeping down the mountain on hill slopes (Particularly, during rainy seasons) while the floor is under repairs and no counterweight is available due to diversion of river waters.

q) *Quality Control*

Safety of the barrages/weirs depends on the sound construction with strict quality control. Safety shall not be compromised for cost or speed of construction. To prevent possible failures, the spots where faulty construction has occurred shall be identified by non-destructive tests and suitable measures taken with strict quality control.

Alkali aggregate reaction sometimes causes expansion of concrete at a much later stage after construction. Sometimes, such expansion in peirs and abutments james the gates. It is essential that the cement and the aggregate proposed to be used in the construction of the barrage or the weirs should be tested in a competent laboratory for alkali-aggregate reactivity. Use of pozzolana material, for example, fly ash, etc, to a considerable extent (up to 40 percent of the cement quantity) may reduce the alkali aggregate reactivity. All the cement and aggregates which are liable to such reaction should be avoided in the construction.

r) Strict quality control during construction should be exercised so that the following construction defects do not occur and the safety of structure is ensured.

1) Stratification of concrete layers in the solid floor and the improper bond between the layers of concrete.
2) Various construction and structural design defects.
3) Cracks in the downstream glacis leading to short circuiting of seepage path.
4) Improper foundation treatment leading to subsidence and consequent disturbance in the alignment of gate track and jamming.
5) Cracking of seals in the joints.
6) Tearing of sheet piles and improper interlocking.
7) Improper foundation treatment of impervious layers leading to locked up seepage pressure.
8) Inadequate cover for reinforcement bars.
9) Honeycombing of bottom layers of floor concrete due to omission of inadequate mudmat.
10) Improper concrete mix used resulting in structural failure, etc.
11) Necking failures of flexible concrete cut off walls.
12) Rigid sheet piles instead of hinged ones due to non-provision of tar paper, cork mastick, asphalt, etc.

8 SAFETY ASPECTS ON MAINTENANCE AND OPERATION

8.1 Proper inspection, maintenance and operation of the diversion structures are necessary adjuncts to safe and economical designs. Any slackness in these aspects would lead to failures and extension of damages. For guidelines on this aspect, reference may be made to IS 7349 : 1989.

8.2 Safety against faulty gate regulation can be prevented only by imparting adequate knowledge to the operating personnel about the significance of the proper regulation and proper maintenance of the gates and other hoisting arrangements. They shall also be imparted adequate training in this regard. These shall form part of the duties of the site-in-charge. Operation and maintenance manual of gates should be updated.

"A group of engineers including the designers, model research officers and maintenance engineers may form a committee of gate regulation. This committee may meet twice a year, once immediately before the flood and once immediately after the flood. The committee shall review the condition of the river, both upstream and downstream of the barrage utilising the cross-sections taken of the river. Whenever serious scour is taking place, the committee may advice repair work by crated boulders etc, where high shoals have been formed near the barrage, both upstream and downstream, proper deshoaling measures either by dredgers or by dozers during the non-monsoon period are to be recommended. Any bank scour near the barrage will also be carefully surveyed and remedial measures to be quickly designed. If quick decisions are not taken, aggrevations may become beyond the control of the maintenance engineers.

Sometimes, the under sluice tunnels are choked due to heavy silt deposition. This should be regularly checked after closing the tunnel gates on the downstream. If necessary, such chokages are to be cleaned by compressed air or air water jets".

8.3 Safety of the barrages against scour damages resulting from cross flows, shoal formation, vortex formation, etc, shall be ensured by proper operation of the gates and dredging of shoals wherever necessary.

8.4 The piezometric data shall be regularly checked, particularly during and after the floods and suitable action taken if unusual behaviour different from the design values are observed. Readings of tiltmeters installed over abutments, piers and divide walls shall be regularly observed and safety of the structure ensured whenever adverse behaviour is observed. Similarly, the readings of soil meters and stress meters, wherever provided, shall be analysed and suitable action taken to ensure safety of the structure.

8.5 Safety of the trash racks provided sometimes upstream of the gates of the head regulator feeding hydel channels shall be ensured by frequently cleaning the clogged openings, thus eliminating high differential pressures to develop.

8.6 Divide walls analysis of scour holes and year to year maintenance required should be examined from hydraulic performance, gate operations and flow phenomenon. If the scour holes are deepened to vortex formation leading to washing of fine due materials and sinking boulders, remedial measures should cover treatment of proper fibre filter.

9 MISCELLANEOUS

9.1 For each and every barrage/weir, a record of its construction features and behaviour, both

hydraulic and structural, shall be kept in the office of the Divisional Engineer of the project. The record shall also contain the details of its failures/problems, if any, and remedial measures adopted from time to time. Necessary photographs shall also be available of the same. These would always help for future modification if any, needed for the safety of the structure.

Construction details, design calculations and construction drawings of barrages/weirs, etc, should be documented and preserved for future reference and use.

River plan forms in the vicinity of barrage should be monitored from ground survey as well as from satellite imageries if possible. Model studies should be carried out before design and construction of barrage/weir.

9.2 Whenever there is any problem or failure of the barrage/weir, a lot of data needs to be collected for study and analysis so that suitable remedial measures could be adopted and safety ensured. A list of such data is given below:

a) Detailed drawings of the barrage/weir, its head regulators, guide bunds, afflux bunds, approach bunds, spurs, etc.

b) Detailed note on the damages noticed including the history and remedial measures carried out, if any, so far.

c) Development of the damages.

d) Photographs taken, if any.

e) Discharge and water levels at various points along guide bunds, afflux bunds, approach bunds, spurs, abutments, etc.

f) Flow pattern observed, for example, concentration of flow through some bays or otherwise.

g) Sounding data both upstream and downstream at the ends of the raft, cement concrete blocks, stone protection around divide walls and for a distance of 60 m or so at 15 m interval.

h) Gate operations followed during floods and other times.

j) Any seismicity experienced prior to or during the floods.

k) Data on settlement of piers, abutments, flank walls, etc, if any.

m) Quantity and quality of bed materials and floating debris during the floods.

n) Details of spurs upstream and downstream.

p) Data on traffic over the structure, if any, during the floods.

q) Details of construction materials used including quality of construction for various components including the different bunds.

r) Instrumentation data available including its analysis and findings.

s) Details about stages of construction.

t) Details of any field investigation done for detecting hollows if any and results thereof.

u) Previous history of any damages and remedial measures thereof.

v) Recommendations of any Technical Advisory Committee from time to time and compliance thereof.

w) Notes on hydraulic and structural designs with assumptions made if any (full details shall be available with the design office).

y) Any other data relevant to the case under investigation.

z) Analysis of discharge, silt charge observations near the barrage and head regulator should be carried out on year to year basis. Gauge discharge relationship and retrogression in the vicinity of barrage, if any, should be taken into consideration for protection measures and river training measures.

9.3 Another important point leading to the safety of the barrage/weir structures being planned, designed, constructed and/or operated and maintained is that of publishing the cases of failures of barrages/weirs and remedial measures adopted in the technical journals for the benefit of the designers and the project authorities. This shall be done wherever feasible subject to orders, if any, regarding publications on projects classified as secret.

Standard Mark

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

Bureau of Indian Standards

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Review of Indian Standards

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