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अनिल जैन
Anil Jain

D.O.No. TE-32/5/2024-NDSA-MOWR/11 Dated.: 01.05.2024

Dear Sh. Bojja ji

Reference is invited to 8141/projects-IV/A1/2021 dated 25.04.2024 vide which I&CAD Department has requested to recommend interim measures to be taken up in respect of Medigadda, Annaram, and Sundilla Barrages of Kaleshwaram Project before onset of coming monsoon to prevent further damage to the barrages.

The Committee constituted by NDSA vide office order TE-32/5/2024-NDSA-MOWR-PART (1) dated 02nd March 2024 for inspection and study of the designs and construction of Medigadda, Annaram, and Sundilla Barrages of Kaleshwaram Project, Telangana State has been examining various aspects and issues related to these barrages. The Committee has examined this aspect as well and has made certain recommendations in respect of interim measures which are required to be taken before the onset of coming monsoon.

Further, in order to ascertain the reasons leading to the sinking of Medigadda Barrage and causes of other distresses in the three barrages, Committee has also recommended certain studies/ investigations in the three barrages before the onset of coming monsoon.

Based upon the submissions made by the Committee, the recommendations on the interim measures and further studies/investigations to be taken up by Irrigation & CAD Department, before the onset of coming monsoon in respect of these barrages, is enclosed along with as Annexure – I.

With Regards

Yours Sincerely

Encl: Annexure – I

(Anil Jain)

Sri Rahul Bojja, IAS
Secretary
I & CAD Department
Govt. of Telangana

Copy for kind information to PS to Hon'ble Minister of M/o Jal Shakti

ANNEXURE – I

RECOMMENDATIONS ON THE INTERIM MEASURES AND FURTHER STUDIES/INVESTIGATIONS TO BE TAKEN UP BY IRRIGATION & CAD DEPARTMENT, BEFORE THE ONSET OF COMING MONSOON

1.0 SITE APPRECIATION AND INTERACTION WITH STAKEHOLDERS

The Committee constituted by NDSA conducted inspection visit to Medigadda (Laxmi), Annaram (Saraswathi) and Sundilla (Parvathi) barrages of Kaleshwaram project during 6th to 9th March 2024, and held discussions at project site, as well as at 'Jalasoudha' Building, Hyderabad with officials of Irrigation & CAD Department and other concerned stakeholders/agencies (Govt./ PSU/ Private etc.). The interaction meetings with concerned stakeholders/agencies were continued during 20th to 22nd March 2024 at Hyderabad office of I&CAD and later during 3rd and 4th April 2024 at NDSA office, New Delhi. The Committee sought information pertaining to the barrages and related issues through Questionnaires, served by the Committee to concerned heads of the units in the I & CAD Department as well as to the concerned heads of other stakeholders/agencies.

The Committee visited the barrages along with the I &CAD team led by Engineer-in-Chief (O&M) and Chief Engineer (Ramagundam) and officials from the respective agencies/stakeholders. The status of the visible damages and distress as observed by the Committee at the three barrages during the visit is presented below.

1.1 MEDIGADDA (LAXMI) BARRAGE

The Medigadda barrage was inaugurated in June 2019 and thereafter, water was impounded in its reservoir. Immediately after the first monsoon in 2019, damages were observed to the downstream CC blocks and apron. However, the impounded water was not released for repair and rectification, instead the barrage reservoir continued to be used for its stated purposes.

The Committee inspected the Medigadda barrage site on the 7th of March 2024. Select approachable locations of the barrage from road bridge deck slab, walkway, river bed locations on the upstream and downstream of the barrage along block nos. 6 to 8, barrage raft at upstream and downstream including the gates, were inspected. As block nos. 1 to 5 were inaccessible due to presence of water, the inspection of the upstream and downstream areas in these blocks could not be conducted. The longitudinal sectional details of the barrage are shown below in *Fig-1*.

The barrage structure is 1632 m long and 20.1 m in height. The length of the barrage is divided into 8 blocks. As reported to the Committee, on 21st October 2023, at around 6.20 pm, sinking of road bridge panels and parapet wall in Block No-7 was noticed with loud sound heard up to control room located about one km. The visiting inspection team from I&CAD on 22.10.2023, besides the structural damages to the pier, have also reported a slow whirling action of water upstream of Pier no 20, two sand boils on downstream side of Block-

7 in the bays between Pier nos 16 and17 and between Pier nos 17 and 18. The stored water from the barrage was immediately released downstream.

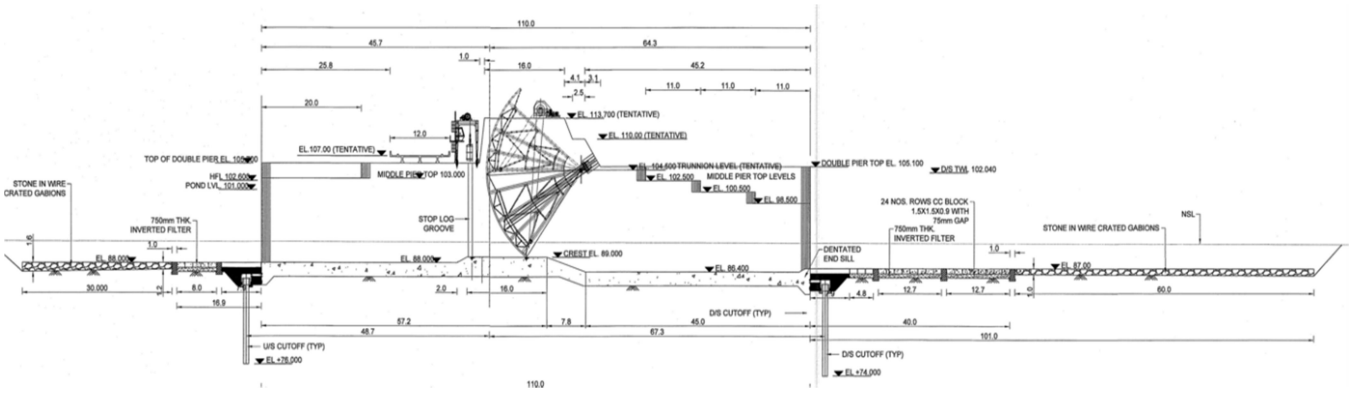


Fig.-1 Longitudinal sectional details of Medigadda (Laxmi) barrage

1.1.1 DISTRESS

Block No. 7 of the barrage comprises of Pier nos. 11 to 22. The Pier nos. 16 to 21 have undergone settlement to varying depths, and tilting to varying degrees. Cracks have developed in these piers and raft floor of Block-7. The settlement of the piers along with the raft is decreasing from upstream end to downstream in all the piers. The Pier no 20 at its upstream end along with the raft has settled by over 1.2 m. Wide structural crack has developed in pier 20, visibly ranging from a width of around 70 mm near gate crest to around 300 mm at the pier top, extending from the junction of pier and raft to the top of pier, traversing along the upstream periphery of the guide rail of the radial gate at Pier no 20. The reinforcements along the crack for full height of pier have failed. Cracks have developed in the piers on the downstream of the radial gate as well. Structural cracks are also noticed in the adjacent piers. Gantry girder and gantry rail alignment is distorted in horizontal direction in few of the piers. Welding joints between the two gantry girders over pier are distorted. The measured levels after sinking of raft and upstream plinth slab of block no.-7 is shown at *Fig.-2*, which points to the fact that the magnitude of the settlement failure in Block No -7 is quite extensive.

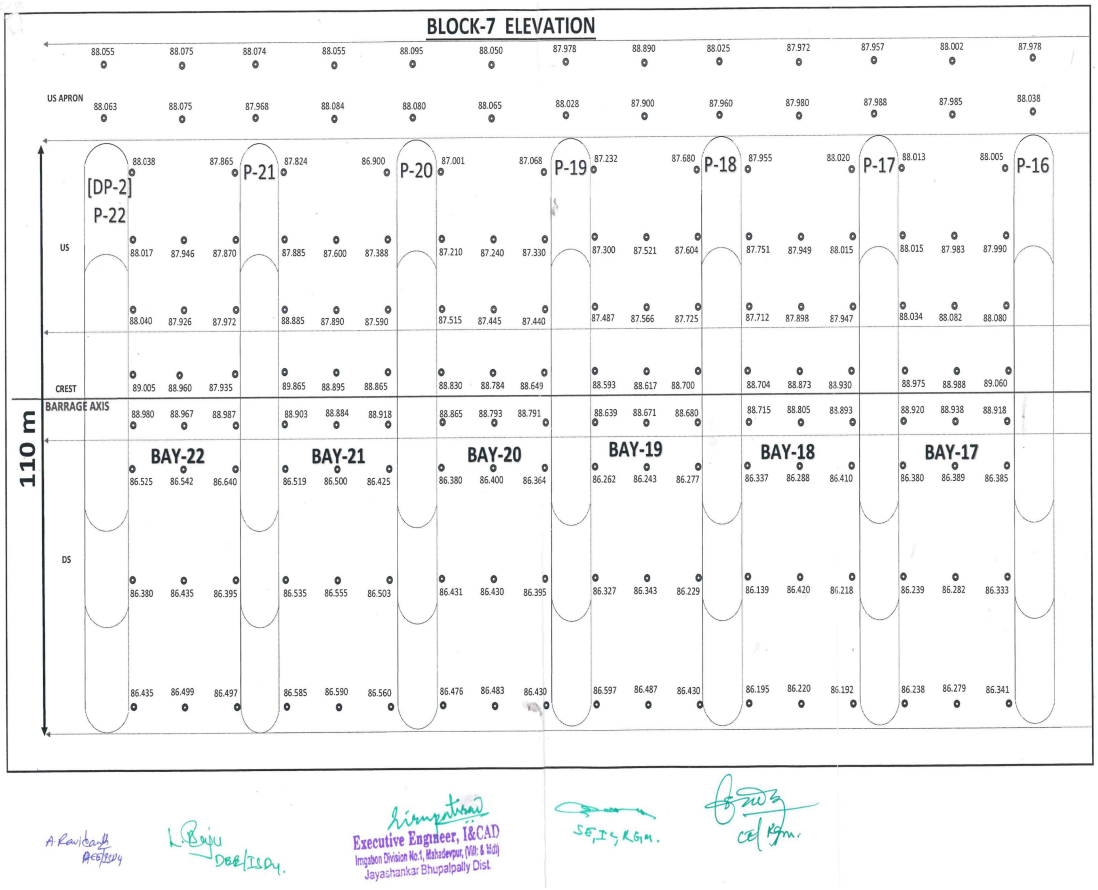


Fig.-2 Measured levels after the sinking of raft of Block No. -7

The Cement Concrete (CC) blocks and launching apron in the downstream have either settled, damaged, dislodged or washed far away, as noticed almost along the entire length of the barrage. The plinth slab upstream and downstream has got damaged, settled or displaced at many places. The wearing coat in the barrage sill and downstream raft in many bays was noticed to be damaged / washed away. The waterway of end blocks (1 and 8) appeared partially obstructed on account of constriction in the river cross-section due to river bank protrusions. The plinth slab was seen to be cracked / destabilized / dislocated at various locations.

1.2 ANNARAM BARRAGE

The Committee inspected the Annaram barrage site on the 8th of March 2024. Select approachable locations of the barrage from road bridge deck slab, river bed locations on the downstream of the barrage and in the upstream, barrage raft at upstream and downstream including the gates, were inspected. The downstream areas inaccessible due to presence of

water could not be inspected. The condition of the CC blocks in the upstream of the Barrage could not be shown to the Committee for almost the entire length, as there was piled-up sand in heaps on the upstream, in front of the barrage raft. The barrage is 1278 m long and 19.85 m in height. The longitudinal sectional details of the barrage are shown below in *Fig-3*.

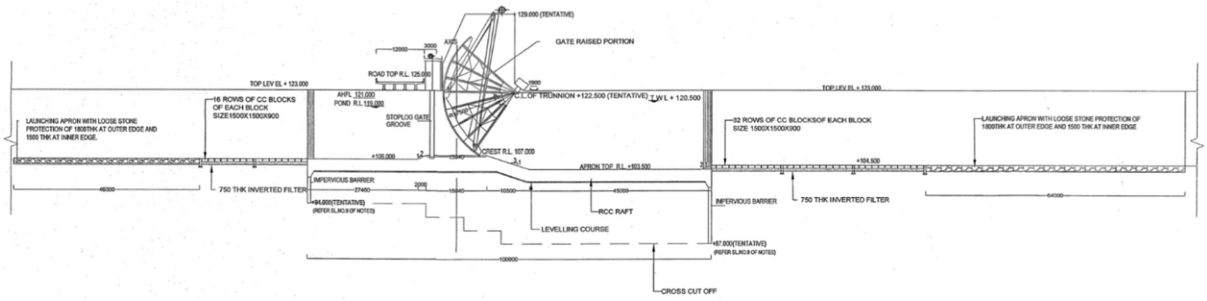
During the visit of this Committee, the river was dry, however pools of water was noticed in front of many blocks. Some of the significant site observations of the Committee are brought out here.

1.2.1 DISTRESS

It was reported that the Cement Concrete Blocks at the downstream of the barrage were first dislodged in the year 2019, during the first monsoon season, post commissioning. Again, during the monsoon season of 2020, the CC blocks were dislodged, and the wearing coat in the raft was also washed away at places. Further, in April 2020, significant seepage was observed near the downstream side of end sill of Bay Nos 35 and 44, which was arrested using polyurethane grouting. Again, in January 2021, significant seepage was observed near the downstream side of the end sill of Bay Nos 28 and 38, which was arrested using polyurethane grouting in January 2024. Sand boiling condition has also been reported. After arresting the seepage in Bay 38, significant seepage was observed in Bay 35, near the downstream side of end sill, which again was arrested using polyurethane grouting in February 2024.

During the visit, the CC blocks and launching apron at the downstream were seen damaged / settled / displaced for almost entire length of barrage. The wearing coat in the barrage sill / glacis / stilling basin was seen dislodged, damaged and washed away in several bays. Huge sand heaps were seen accumulated upstream in front of the barrage bay raft, for almost the entire length of the barrage. Hence the upstream areas of the barrage could not be inspected.

Fig.-3



Longitudinal sectional details of Annaram (Saraswathi) barrage

1.3 SUNDILLA (PARVATHI) BARRAGE

The Committee inspected the Sundilla barrage site on the 8th of March 2024. Select approachable locations of the barrage from road bridge deck slab, river bed locations on the downstream of the barrage, barrage raft at the downstream were inspected. The Committee could not inspect the upstream area of the barrage in the river bed as water up to some depth above the crest level was stored. The barrage is 1452 m long and 19.48 m in height. The longitudinal sectional details of the barrage are shown below in *Fig-4*.

During the visit of this Committee, the river in the downstream was predominantly dry, except for pools of water noticed in front of some blocks. The downstream areas inaccessible due to presence of water could not be inspected. Some of the significant site observations of the Committee are brought out here.

1.3.1 DISTRESS

It has been reported that the Cement Concrete Blocks at the downstream of the barrage were first dislodged in the year 2019, during the first monsoon season, post commissioning. The wearing coat of raft was also dislodged at places or washed away. Further, in May 2020, significant seepage was observed near the downstream side of end sill in Bay 46 and Bay 52, which was arrested using polyurethane grouting. In August 2022, CC blocks were either dislodged or settled, and wearing coat was damaged / dislodged at many places. Again, in October 2023, seepage was observed near downstream side of end sill of Bay Nos 33 & 50, which was arrested using polyurethane grouting.

During the visit, the CC blocks and launching apron at the downstream were seen damaged / settled / displaced for almost entire length of the barrage.

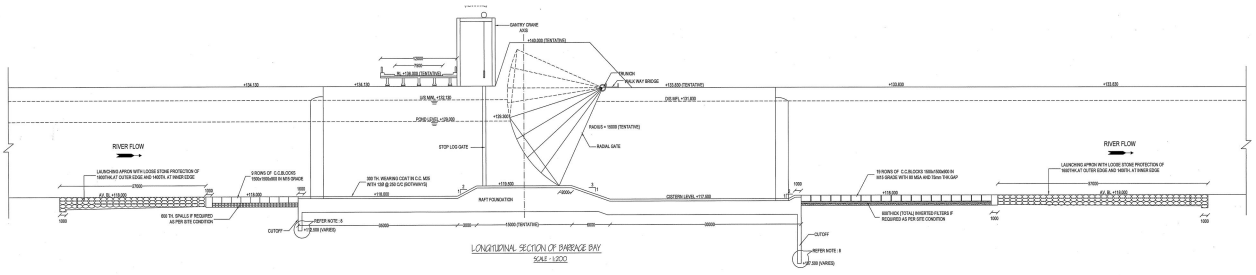


Fig.-4 Longitudinal sectional details of Sundilla (Parvathi) barrage

2.0 RECOMMENDATIONS ON INTERIM MEASURES BEFORE THE ONSET OF COMING MONSOON

The Committee, based on the visual inspection at the site of barrages, interactions with I&CAD Department officials and other concerned stakeholders, and initial round of examination of the documents submitted, recommends the following interim measures to be taken up before the onset of coming monsoon of 2024.

2.1 RECOMMENDATIONS ON INTERIM MEASURES IN RESPECT OF BLOCK NO- 7 OF MEDIGADDA BARRAGE

The I&CAD Department has informed the Committee that 77 out of 85 radial gates in Medigadda Barrage have been successfully lifted. However, problems have been encountered while lifting the

remaining radial gates i.e. No. 15 to 22 in the distressed Block No-7. The Committee has been requested to suggest the way forward on the lifting of the remaining eight radial gates for carrying out the works before the onset of the coming monsoon.

The lifting of the remaining eight radial gates relates to Block No-7 of the Barrage. The Block No-7 on which the remaining eight radial gates are resting, is in a '*highly distressed state of condition'*. The piers along with the raft in Block No-7 have sunk to varying depths and piers tilted to varying degrees. The worst affected Pier No 20, which has sunk by over 1.2 m is precariously standing, with the reinforcement completely sheared off along the wide-crack. The crack is running along the full height of the pier, just upstream of the radial gate wall plate of Pier No. 20. Wide cracks have also developed at many other locations in the upstream and downstream of the piers and raft of Block No-7. In this process, the radial gate and its hoisting mechanism have also experienced distress.

At the upstream location of the sunken Pier No 20, the settlement of raft along with the pier has exposed the space between the secant pile cut-off and the concrete plinth slab. At the downstream end of the piers, the plinth slab above the secant pile is damaged. Sand piping holes are observed upstream of Pier No-20 and downstream of Pier No. 17-18. The condition of the sub-surface components viz. secant pile and pile-raft joint system, cavities underneath the raft and related information are still to be thoroughly investigated. Under the given circumstances, any remedial measure for Block No-7 would be an interim measure only, primarily to maintain the status quo of distressed condition. However, it is pertinent to mention that the possibility of any further unexpected movement or behavior of structure in such a highly distressed condition cannot be ruled out, despite interim measures.

1. The following activities/measures shall be carried out in the given sequence below for Block No.-7:
    a. Crack monitoring at appropriate locations shall be carried out to an accuracy of +/- 1.0 mm, through appropriate techniques such as tell-tales etc., for continuous monitoring of the movement across all the cracks in piers and raft floor.
    b. Pier nos. 16 to 22 have either tilted or have developed cracks to varying magnitude. These piers shall be adequately braced at appropriate locations with suitable bracing system. Lattice girder/truss or box girder can also be used to arrest any likely lateral movement. While doing so, adequate precautions shall be taken that no heavy loads are transferred on to the raft.
    c. Defective or damaged Pressure Release Valves in the raft shall be rectified or replaced.
    d. Optical targets shall be installed on top level of all piers of Block No-7, one each at the upstream end, at the downstream end and at the middle, which shall be continuously monitored through a Total Station, and record maintained.
    e. The condition of the upstream & downstream secant pile and the condition of the upstream & downstream parametric joint shall be assessed as detailed in Section -5.
    f. Plinth slab which has been settled / displaced / damaged (upstream and downstream) shall be removed and the river bed shall be properly compacted, inverted filter laid and leveled up to desired level. The damages to the plinth slab/end-sill noticed at

certain locations may be repaired / recast. If boiling is noticed underneath the plinth slab, the same shall be arrested by restoring the parametric joint at that location, and the area shall be well compacted and plinth slab recast. The raft of block no 7 has settled to varying depths with respect to upstream plinth slab, exposing the top area of the parametric joint at some locations. At these locations, sand filled bags shall be placed against the vertical face of the plinth slab at a slope of 1:3 or flatter. A cement sand (1: 3) layer of adequate thickness may also be placed at surface of slope.

g. Drive sheet pile just downstream of downstream plinth slab, up to a minimum of 9 m depth, after completing the geophysical investigations to assess the condition of secant pile and parametric joint recommended under Section-5. The report of geophysical investigations already carried out using Electrical Resistivity Tomography (ERT), along the downstream ERT line could provide information about the likely sub-surface conditions while driving the sheet pile. The joints at the top of the plinth slab, in the space between the end sill and sheet pile shall be effectively sealed by grouting with shrink-adjusted rich cement sand mortar as shown in *Fig. - 5*, so that no seepage takes place.

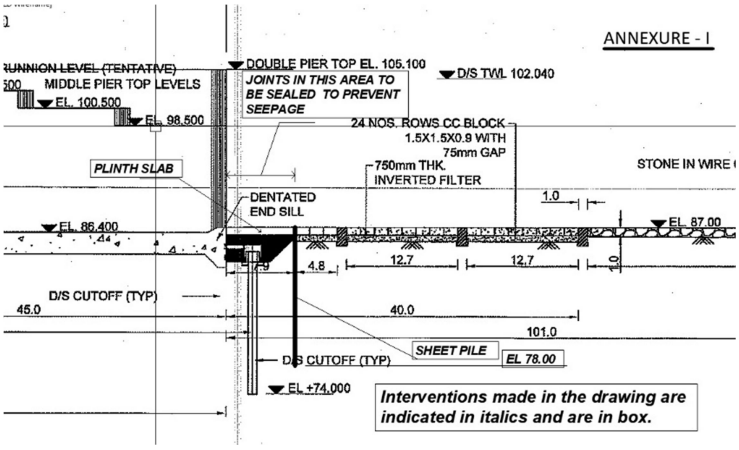


Fig.-5 Location of sheet pile to be driven and area to be sealed at downstream plinth slab

h. The delineated cavity/anomalous zones underneath the raft at locations as indicated in the GPR survey report, may be verified by I & CAD. Cement: sand: water grout shall be used to fill the cavity. Minimum number of holes (of size 48 mm to 76 mm dia) shall be drilled in the raft for grouting purpose. Before grouting, the volume of the cavity may be assessed through a bore hole camera and documented, and further geotechnical investigations carried out as detailed under Section -5. The depth of the hole shall be restricted to 2 m below the raft or up to the depth of the delineated cavity/anomalous zones, whichever is less. Cement : sand ratio shall be kept in the range of 1:5 to 1:3, starting with leaner mix. Medium to fine sand shall be preferred depending on flowability requirements. Quantity of water will also depend on flowability requirement. To increase flowability and to reduce shrinkage, suitable admixture may also be added as per site condition. Grouting pressure need to be limited to 1 kg/cm^2 to avoid uplift of raft. The grouting shall be done till refusal.

The bore holes shall be suitably plugged after completion of grouting. Any leakage of grout/water from u/s and d/s end of raft or from the cut-offs / parametric joint during the grouting is to be monitored, documented, and suitably addressed.

2. In order to avoid/minimize hydraulic forces on gates as well as structure, all Gates of Block 7 shall be lifted to fully opened position before onset of monsoon. Before doing so, all the components of the radial gate such as skin plate, horizontal girders, arms, trunnion bracket, trunnion pin, bush, trunnion/yoke girder, anchorages, trunnion assembly alignments, seal assembly, side rollers, wall plate assembly, lifting arrangements, hoist bridge, wire rope, stoplogs, gantry crane etc., in respect of each gate shall thoroughly be checked for integrity of components and their joints with other components along with clearances, and commensurate remedial measures, as required, shall be carried out. In respect of radial Gate Nos 15 to 22 of Block No-7, which are not opening due to sinking of piers, following sequence of activities shall be followed for their lifting/ removal:
    a. Gantry crane shall be parked at any block other than Block No-7.
    b. All the distressed piers shall be braced suitably as mentioned above, before lifting these eight distressed radial gates.
    c. Connection of ropes at fixed ends and all the pulleys connection shall be thoroughly checked for their firmness and integrity. Ropes shall also be checked for its slackness / looseness to avoid tilting of gate while lifting.
    d. All the welds, bolts and pin connections in gate, hoist and its supporting structures shall be checked thoroughly for their integrity, before any of these gates is lifted.
    e. The extent of gap of the side seal and guide roller with wall plate shall be checked. In case compression of seal is more than permissible, side rubber seals and guide rollers shall be removed.
    f. Radial Gates adjacent to Pier no 20 (i.e. Gate No 20 & 21), which has suffered the maximum damage, shall be removed completely by dismantling and/or cutting the gate from trunnion assembly, and taken away.
    g. The remaining six gates shall be lifted to fully open position and shall be latched/dogged firmly. In case of any difficulty in lifting any of these gates to fully open position, the gate shall be removed completely as given in (vi) above.
    h. Gate shall be cautiously lifted and the motor shall be monitored for any unusual heating or sound, which may be the indication of increase of load on motor. If gate is stuck during the lifting, which may most likely be on account of tilting of piers, suitable width of skin plate of the gate along the side seal shall be cut, to create sufficient gap between the wall plate and the radial gate, so that gate is lifted to fully open position. The cutting of the radial gate shall be carried out while resting on sill beam.
3. The CC Blocks upstream & downstream of Block-7, which have been settled / displaced / damaged shall be removed and the river bed shall be properly compacted, inverted filter laid and leveled up to desired level. Wherever boiling is noticed, the same shall be arrested by sand compaction in layers before laying inverted filter and CC blocks.

4. The CC blocks which are intact may be used again. However, damaged CC blocks may be replaced. The dislodged d/s launching apron along with toe wall shall be restored back to its original approved drawings.
5. The first three rows of CC blocks downstream of the plinth slab of Block-7 up to first downstream toe wall shall be interconnected with each other at the top through suitable rebars, so that they do not get displaced easily, yet function as flexible protection.

2.2 RECOMMENDATIONS ON INTERIM MEASURES IN RESPECT OF BLOCK NOS 1 TO 6 AND BLOCK NO 8 OF MEDIGADDA BARRAGE

The Committee recommends the following interim measures to be undertaken for Block Nos 1 to 6 and Block No 8, before the onset of upcoming monsoon of 2024.

1. The condition of the upstream & downstream secant pile and the condition of the upstream & downstream parametric joint shall be assessed.
2. Plinth slab which has been settled / displaced / damaged (upstream and downstream) shall be removed and the river bed shall be properly compacted, inverted filter laid and leveled up to desired level. The damages to the plinth slab/end-sill noticed at certain locations may be repaired / recast. If boiling is noticed underneath the plinth slab, the same shall be arrested by restoring the parametric joint at that location, and the area shall be well compacted and plinth slab recast.
3. In order to avoid/minimize hydraulic forces on gates as well as structure, all Gates shall be lifted to fully opened position before onset of monsoon. Before doing so, all the components of the radial gate such as skin plate, horizontal girders, arms, trunnion bracket, trunnion pin, bush, trunnion/yoke girder, anchorages, trunnion assembly alignments, seal assembly, side rollers, wall plate assembly, lifting arrangements, hoist bridge, wire rope, stoplogs, gantry crane etc., in respect of each gate shall thoroughly be checked for integrity of components and their joints with other components along with clearances, and commensurate remedial measures, as required, shall be carried out.
4. The upstream & downstream CC Blocks, which have been settled / displaced / damaged shall be removed and the river bed shall be properly compacted, inverted filter laid and leveled up to desired level. Wherever boiling is noticed, the same shall be arrested by sand compaction in layers before laying inverted filter and CC blocks.
5. The CC blocks which are intact may be used again. However, damaged CC blocks may be replaced. The dislodged d/s launching apron along with toe wall shall be restored back to its original condition as per the approved drawings.
6. The first three rows of CC blocks downstream of the plinth slab up to first downstream toe wall shall be interconnected with each other at the top through suitable rebars, so that they do not get displaced easily, yet function as flexible protection.
7. All obstructions to the smooth and even distribution flow of water through barrage and its immediate upstream and downstream shall be removed and ground trimmed. The left-over boulders and debris, dead concrete, sheet piles, shoals or sediment deposits and any other protrusions, that obstruct the smooth flow in the upstream as well as downstream, in front of all the barrage bays in all the 8 blocks shall be removed.

2.3 RECOMMENDATIONS ON INTERIM MEASURES IN RESPECT OF ANNARAM BARRAGE AND SUNDILLA BARRAGE

1. The condition of the upstream & downstream secant pile and the condition of its joint with raft shall be assessed.
2. In order to avoid/minimize hydraulic forces on gates as well as structure, all Gates shall be lifted to fully opened position before onset of monsoon. Before doing so, all the components of the radial gate such as skin plate, horizontal girders, arms, trunnion bracket, trunnion pin, bush, trunnion/yoke girder, anchorages, trunnion assembly alignments, seal assembly, side rollers, wall plate assembly, lifting arrangements, hoist bridge, wire rope, stoplogs, gantry crane etc., in respect of each gate shall thoroughly be checked for integrity of components and their joints with other components along with clearances, and commensurate remedial measures, as required, shall be carried out.
3. First four rows of downstream CC blocks shall be removed for the entire length of the Barrage. Thereafter, the river bed shall be properly compacted & leveled up to the desired level over which an inverted filter shall be laid. A woven geotextile filter, designed with appropriate strength and filter characteristics shall be laid on the inverted filter. It shall be ensured that the formation below the geotextile filter is free of stones and boulders to ensure that geotextile filter is not punctured. The upstream end of the geotextile filter shall be duly secured with end sill of the raft. CC blocks shall be placed over the geotextile filter. These CC blocks shall be interconnected with each other at the top through suitable rebars, so that they do not get displaced easily, yet function as flexible protection.
4. The upstream CC Blocks & remaining downstream CC Blocks (beyond first 4 rows), which have been settled / displaced / damaged shall be removed and the river bed shall be properly compacted, inverted filter laid and leveled up to desired level before relaying CC blocks.
5. Wherever boiling is noticed, the same shall be arrested by sand compaction in layers before leveling river bed.
6. The CC blocks which are intact may be used again. However, damaged CC blocks may be replaced. The dislodged d/s launching apron along with toe wall shall be restored back to its original condition as per the approved drawings.
7. In case of Annaram barrage, the sand heaps accumulated in front of the barrage bay raft shall be suitably removed and the waterway cleared, strictly adhering to the norms of I&CAD Department or other regulations in this regard, for removal of sand from the river.
8. All obstructions to the smooth and even distribution flow of water through barrage and its immediate upstream and downstream shall be removed and ground trimmed. The left-over boulders and debris, dead concrete, sheet piles, shoals or sediment deposits and any other protrusions, that obstruct the smooth flow in the upstream as well as downstream, in front of all the barrage bays shall be removed.

The design and drawings required to execute the above recommended remedial measures shall be finalized by I&CAD. Adequate resource mobilization and timely execution of the works before onset of coming monsoon 2024 shall be ensured by I&CAD.

3.0 RECOMMENDATIONS ON FURTHER STUDIES AND INVESTIGATIONS BEFORE THE ONSET OF MONSOON

In order to ascertain the reasons leading to the sinking of Medigadda Barrage and causes of other distresses in the three barrages, certain geophysical and geotechnical investigations in the barrage area, as well as certain tests to assess the structural integrity of the barrage structure & related appurtenances are necessary. These are to be carried out before the onset of the coming monsoon.

3.1 MEDIGADDA BARRAGE

3.1.1 General

a) River cross sections for a distance of 5000 m from the centerline of the barrage, both on the upstream and downstream, at every 100 m interval shall be taken (including bathymetry).
b) The levels of upstream and downstream area of barrage, including Plinth slab, CC Blocks and launching apron shall be taken (including bathymetry).
c) Observations of Gauge as well as Discharge through ADCP etc., at upstream and downstream, for validation of the Gauge-Discharge curve for low flows to as high flows as possible.
d) The surface crack mapping of entire barrage structure may be undertaken using a high-resolution camera mounted on a UAV (drone).
e) The precision survey/levelling of the civil components viz. raft, piers and bridge deck slab as well as the hydro mechanical components of the barrage, to an accuracy of one mm, for recording the horizontal and vertical deformations with reference to design levels may be carried out.

3.1.2 Geophysical Investigations

The Geophysical investigations, comprising of Ground Penetrating Radar (GPR) survey on the barrage raft and Electrical Resistivity Tomography (ERT) on the upstream and downstream of the barrage has been carried out. The qualitative results obtained from the geophysical investigations need to be verified through bore hole investigations, which are to be carried out before the coming monsoon.

Further geophysical investigations, to assess the integrity/ continuity of upstream and downstream secant pile cut off and parametric joint shall also be carried out before the coming monsoon as detailed below.

a) Parallel seismic method shall be carried out to check the continuity/ integrity of the upstream and downstream secant piles cut off in Block no 7.

b) Under parallel seismic method in Block 7, holes at a spacing of 15-20 m (having depth 2 m deeper than bottom elevation of nearer secant cutoff) shall be drilled for installation of receivers downstream of downstream cut-off and upstream of upstream cut-off. The boreholes shall be as close to the secant piles as possible.
c) The signal shall be generated by suitably hammering on the plinth slab (upstream and downstream respectively), which shall be picked up by the receivers installed in the boreholes.

3.1.3 Geotechnical Investigations for assessing the Barrage foundation

For carrying out Geotechnical investigations for assessing the barrage foundation, two boreholes shall be drilled in each bay of Block-7. The depth of boreholes shall be 25 m.

a) One bore hole in each bay shall be located in the raft upstream of gate, whereas the second hole shall be located in the raft downstream of gate.
b) The upstream borehole shall preferably be located where the cement-sand grouting is to be carried out and shall subsequently be used for grouting.
c) The downstream borehole location shall preferably be located 4 m upstream of downstream edge of raft at the center of each bay.
d) Entire depth of 25 m of borehole shall be logged and recorded. Appropriate tests to assess the dissolubility of rock cores shall be undertaken. In case cavity is encountered during drilling, it shall be properly recorded, documented and further drilling shall continue up to the desired depth.
e) Standard Penetration Test (SPT) at every 1.5 m depth shall be carried out in each borehole. The SPT samples shall also be collected and tested for index properties. (e.g. grain size distribution, Atterberg limits etc.) Permeability Test at every 3 m depth shall also be carried out in each borehole.
f) Undisturbed samples shall be collected at every 2 m depth in each borehole for determination of index properties (e.g. grain size distribution, Atterberg limits, specific gravity etc.), consolidation characteristics and shear strength parameters of foundation material.
g) Cavities if any, encountered, during the drilling shall be grouted as recommended in the interim measures (section 4), after the completion of geotechnical investigations in that hole.
h) The drill holes shall be suitably refilled to ensure foundation competency and plugged to ensure raft integrity after completion of investigation.
i) Alternate bore holes in downstream raft shall be used for installation of vibrating wire piezometers in order to assess the sub surface flow conditions.

3.1.4 Investigations on the Concrete Structures

Investigations on concrete structures i.e. piers and raft between Piers no. 16 to 21 of Block no. 7 shall be carried out to assess the concrete quality including, homogeneity, in-situ strength and structural integrity.

a) Rebound hammer shall be carried out on the easily accessible surfaces of piers and raft near the mapped cracks at a reasonable number of locations to evaluate the surface strength.
b) Based on rebound hammer test results, Ultrasonic Pulse Velocity (UPV) test shall be performed in the areas of concern.
c) Post analysis of UPV test results, any test location where the concrete quality is deemed doubtful or of poor quality, shall be tested for in-situ compressive strength using the CAPO testing apparatus.
d) In addition to NDT tests, at least a set of 3 concrete cores of minimum 100 mm dia (preferably length 200 mm) from each bay of raft shall also be extracted representing the full depth. Similarly, at least 3 cores shall also be extracted from each pier. These cores shall be tested for density, compressive strength and other related parameters as per codal provisions of IS 516. This will also help in validation of NDT results.
e) The boreholes made in raft shall be plugged for full depth to ensure raft integrity.

Rebound Hammer and Ultrasonic Pulse Velocity (UPV) shall be carried out as per provisions of Standard: IS 516 (Part 5): 2020. Cut And Pull Out (CAPO) shall be carried out as per provisions of ASTM C900.

3.2 ANNARAM BARRAGE

3.2.1 General

a) River cross sections for a distance of 5000 m from the centerline of the barrage, both on the upstream and downstream, at every 100 m interval shall be taken (including bathymetry).
b) The levels of upstream and downstream area of barrage, including Plinth slab, CC Blocks and launching apron shall be taken (including bathymetry).
c) Observations of Gauge as well as Discharge through ADCP etc., at upstream and downstream, for validation of the Gauge-Discharge curve for low flows to as high flows as possible.
d) The surface crack mapping of entire barrage structure may be undertaken using a high-resolution camera mounted on a UAV (drone).
e) The precision survey/levelling of the civil components viz. raft, piers and bridge deck slab as well as the hydro mechanical components of the barrage, to an accuracy of one mm, for recording the horizontal and vertical deformations may be carried out.

3.2.2 Geophysical Investigations

a) Parallel seismic method shall be carried out to check continuity/ integrity of secant piles cut off in bays 26 to 46.

b) Under parallel seismic method, holes at a spacing of 15-20 m (having depth 2 m deeper than bottom elevation of nearer secant cutoff) shall be drilled for installation of receivers downstream of downstream cut-off and upstream of upstream cut-off. The boreholes shall be as close to the secant piles as possible.
c) The signal shall be generated by hammering on upstream and downstream ends of raft respectively which shall be picked up by the receivers installed on the boreholes.

3.2.3 Geotechnical Investigations for assessing the Barrage foundation

a) Geotechnical investigations by drilling one borehole each in bays 28, 35, 38 and 44 shall be carried out. The depth of borehole shall be 25 m.

b) The borehole location shall be located 2 m upstream of the grout hole through which polyurethane grouting has already been carried out in these bays.

c) Entire depth of 25 m of borehole shall be logged and recorded. Appropriate tests to assess the dissolubility of rock cores shall be undertaken. In case cavity is encountered during drilling, it shall be properly recorded, documented and further drilling shall continue up to the desired depth.

d) Standard Penetration Test (SPT) at every 1.5 m depth shall be carried out in each borehole. The SPT samples shall also be collected and tested for Index Properties. (e.g. grain size distribution, Atterberg limits etc.) Permeability Test at every 3 m depth shall also be carried out in each borehole.

e) Undisturbed samples shall be collected at every 2 m depth in each borehole for determination of index properties (e.g. grain size distribution, Atterberg limits, specific gravity etc.) consolidation characteristics and shear strength parameters of foundation material.

f) Cavities if any, encountered, during the drilling shall be grouted as recommended in the interim measures (Section 4), after the completion of geotechnical investigations in that hole.

g) The drill holes shall be suitably refilled to ensure foundation competency and plugged to ensure raft integrity after completion of investigation.

h) Alternate downstream bore holes shall be used for installation of vibrating wire piezometers in order to assess the sub surface flow conditions.

3.3 SUNDILLA BARRAGE

3.3.1 General

a) River cross sections for a distance of 5000 m from the centerline of the barrage, both on the upstream and downstream, at every 100 m interval shall be taken (including bathymetry).
b) The levels of upstream and downstream area of barrage, including Plinth slab, CC Blocks and launching apron shall be taken (including bathymetry).
c) Observations of Gauge as well as Discharge through ADCP etc., at upstream and downstream, for validation of the Gauge-Discharge curve for low flows to as high flows as possible.
d) The surface crack mapping of entire barrage structure may be undertaken using a high-resolution camera mounted on a UAV (drone).
e) The precision survey/levelling of the civil components viz. raft, piers and bridge deck slab as well as the hydro mechanical components of the barrage, to an accuracy of one mm, for recording the horizontal and vertical deformations may be carried out.

3.3.2 Geophysical Investigations

a) Parallel seismic method shall be carried out to check continuity/ integrity of Secant piles cut off in bays 31 to 54.
b) Under parallel seismic method, holes at a spacing of 15-20 m (having depth 2 m deeper than bottom elevation of nearer secant cutoff) shall be drilled for installation of receivers downstream of downstream cut-off and upstream of upstream cut-off. The boreholes shall be as close to the secant piles as possible.
c) The signal shall be generated by hammering on upstream and downstream ends of raft respectively which shall be picked up by the receivers installed on the boreholes.

3.3.3 Geotechnical Investigations for assessing the Barrage foundation

a) Geotechnical investigations by drilling one borehole each in bays 33, 46, 50 and 52 shall be carried out. The depth of borehole shall be 25 m.
b) The borehole location shall be located 2 m upstream of the grout hole through which polyurethane grouting has already been carried out in these four bays.
c) Entire depth of 25 m of borehole shall be logged and recorded. Appropriate tests to assess the dissolubility of rock cores shall be undertaken. In case cavity is encountered during drilling, it shall be properly recorded, documented and further drilling shall continue up to the desired depth.
d) Standard Penetration Test (SPT) at every 1.5 m depth shall be carried out in each borehole. The SPT samples shall also be collected and tested for Index Properties. (e.g. grain size distribution, Atterberg limits etc.) Permeability Test at every 3 m depth shall also be carried out in each borehole.
e) Undisturbed samples shall be collected at every 2 m depth in each borehole for determination of index properties (e.g. grain size distribution, Atterberg limits, specific

gravity etc.) consolidation characteristics and shear strength parameters of foundation material.

f) Cavities if any, encountered, during the drilling shall be grouted as recommended in the interim measures (Section 4), after the completion of geotechnical investigations in that hole.
g) The drill holes shall be suitably refilled to ensure foundation competency and plugged to ensure raft integrity after completion of investigation.
h) Alternate downstream bore holes shall be used for installation of vibrating wire piezometers in order to assess the sub surface flow conditions.

The subsurface investigations shall be carried out as per the provisions of IS Code 13578: Subsurface Exploration for Barrages and Weirs - Code of Practice and IS Code 1892: Code of Practice for Subsurface Investigation for Foundations. Drilling should be carried out using any Rotary Drilling Machines conforming to IS: 6926 (Code of practice for diamond core drilling for site investigation of river valley projects) and capable of making a borehole to the required depth and diameter, without disturbing the soil which is to be sampled. The machine and its accessories should be compatible in collection of undisturbed samples, conducting Standard Penetration Test, determine in-situ permeability in soil and rock and collection of rock cores as per relevant Indian Standards. The machine should be capable of hydraulically pushing the Undisturbed sampling (UD) tubes at steady rate without any jerk and without disturbing the soil which is to be sampled. No hammering should be done in collection of undisturbed samples.

The Committee recommends that for carrying out the above investigations / tests, organizations such as CSMRS, New Delhi / CWPRS, Pune / NGRI, Hyderabad shall be engaged.

Nothing contained herein shall be construed to absolve the dam owner (I&CAD) of the duties, obligations or liabilities incidental to the construction, operation, maintenance and supervision of the dam or reservoir.