mcp/3084
29/02/2024

Date: 29/02/2024

Received today from Prof R.S. Jangid, Prof. V. Jyoti prakash, Prof. D. Murthy and Shri Kandalkar

To,
The Municipal Commissioner,
Brihanmumbai Municipal Corporation,
Municipal Head Office, 1st Floor, Old Building,
Mahapalika Marg, Fort,
Mumbai 400 001.

Subject:- Committee to review reconstruction work of Malabar Hill Reservoir.

Final report of the Committee for review of the Malabar Hill Reservoir.

Dear Sir,

No. D. M. C/SE/730/mc
29 FEB 2024

Please find enclosed herewith the final report from the following four members of the committee on the subject.

29/2/24 C.

for M.M.P.

D.M.C. (S.E.)

A physical meeting of all committee members was held on January 17 at IIT Bombay where it was decided to include everybody's opinion on the report. Accordingly, Dr. Nori has submitted the report prepared by him on 25.1.2024. The views expressed in the above report were agreed upon by Prof. Alok Goyal, Er. Alpa Sheth, and Ar. Rahul Kadri.

However, the views expressed by the following members were not captured as per TOR in the above report. As a result, the following members made additions to the report based on the hydraulic study as per TOR.

Additional Municipal Commissioner (Project)

Prof. Alok Goyal, Dr. Nori, Er. Alpa Sheth, and Ar. Rahul Kadri did not agree to the views expressed by the following members and did not consent to sign the combined report.

As such, a separate report agreed upon by the four following committee members is being submitted herewith.

Accompanying the final report of the undersigned.

Regards,

Prof R S Jangid

Prof V. Jothiprakash

Prof Dasaka Murty

Shri C H Kandalkar

बृहन्मुंबई महानगरपालिका
आयुक्तांचे कार्यालय

29 FEB 2024

समय ११, १२, १३, १४, १५, १६, १७, १८

क्रमांक MCP/ 3084

29/2/2024

बृहन्मुंबई महानगर पालिका
अतिरिक्त आयुक्त (प्रकल्प)
यांचे कार्यालय

29 FEB 2024

क्र. अति.आ./प्रकल्प/ 9476

29/02/2024

D.M.C (SE)

उप आयुक्त (विशेष अभियांत्रिकी)
यांचे कार्यालय
क्र. उप आ./वि.अ./ 730/MC
दिनांक 29/02/2024

बृहन्मुंबई महानगरपालिका
पाणी पुरवठा प्रकल्प
प्रमुख अभियंता यांचे कार्यालय

29 FEB 2024

प्र.अ./पा.पु.प्र./स्विव/ 4899

Chief Engineer
(WSP)

FINAL REPORT OF THE COMMITTEE FOR REVIEW OF MALABAR HILL RESERVOIR

By

Prof. R.S. Jangid,

Prof. V. Jothiprakash,

Prof. Dasaka Murty, and

Shri C.H. Kandalkar

1. BACKGROUND

The BMC appointed M/s. D. D. Kulkarni as a structural consultant for Malabar Hill Reservoir (MHR). The Structural Consultant opined that the structure under consideration is an aged structure, and provision for an alternative new structure (reservoir) arrangement shall be kept ready and implemented as early as possible. The Structural Consultant opined that the reservoir needs reconstruction at the earliest possible date. The report was vetted by Prof. Alok Goyal of IIT Bombay and recommended creating a new 20 ML (or 25 ML) reservoir at a new location for peak demand. Before any reconstruction work is taken up, it was suggested to take up reconstruction work by isolating existing reservoirs out of service one by one with the strengthening of the common wall and with special attention to the demolition of arches. The services of M/s. D.D. Kulkarni were discontinued by BMC, and M/s. Pednekar & Associates was appointed as a consultant for the work, who proposed phase-wise reconstruction of MHR with the creation of a new reservoir of capacity (23+7) ML. The said revised scheme was also vetted by Prof. Alok Goyal, IIT Bombay.

Upon award of the contract, contractor M/s. Skyway Infraprojects Pvt. Ltd. represented BMC, stating that the proposed phase-wise reconstruction scheme described in the contract consisted of very high risk and was full of uncertainties involved in each phase based on the opinion sought from Prof. R.S. Jangid, IIT Bombay, Shri Shashank Mehandale (Structural Consultant), and Prof. Dr. Abhay Bambole, VJTI. Subsequently, M/s Pednekar & Associates suggested increasing the capacity of the new reservoir from 23 ML to 90 ML, which will allow the complete isolation of the existing reservoir and

and allow the MHR to be reconstructed without any risks of hampering water distribution.

In the proposed scheme of reconstruction, 389 trees were noted to be affected (i.e., 189 to be cut and 200 to be transplanted). Local residents, environmentalists, and social activists have opposed the proposal of cutting down trees and are asking for other alternatives to save trees.

In view of the above, the Hon'ble Municipal Commissioner has accorded approval to constitute the present committee for the scope and terms of reference.

2. TERMS OF REFERENCE OF COMMITTEE

The scope of work and terms of reference (ToR) was defined as under:

1. Whether the repairing of the existing Malabar Hill Reservoir is feasible without constructing a new alternative and without affecting the water supply from the MHR.
2. Whether phase-wise reconstruction of the Malabar Hill Reservoir is feasible without affecting the water supply from the MHR? This has zero tolerance i.e. no compromise to disturbance of the water supply to citizens from MHR.
3. The time period for receiving public suggestions/objections shall be 15 days from the date of publishing the email ID. Thereafter suggestions are to be verified on their merits.
4. To study, verify, and opine on the actionable proposal received from the local citizens, public representatives/experts.
5. The time period for study and to give opinion will be one month only
6. IIT Bombay may suggest any other actionable proposal, if any

3. COMMITTEE MEETING AND SITE VISITS

The committee has held two virtual meetings. The first meeting was held on November 21, 2023 [with full attendance except DMC(SE)] and the second meeting was held on December 19, 2023 [full attendance of committee].

Site visits for Compartments 2A and 2B were conducted on December 7, 2023 [All in attendance except Ar. Kadri and Prof. Alok Goyal] and Visit for

1A, 1B and 1C was held on December 18, 2023 [All in attendance except Prof. Goyal].

A physical in person meeting was also held at IITB on January 17, 2024.

4. OBSERVATIONS FROM THE VISUAL INSPECTION OF MHR

Based on the visual inspection of the tanks of the MHR, the following important observations are made:

i. There is structural damage to the tanks of the MHR in the form of (a) corrosion of steel reinforcement and spalling of the concrete cover of the RCC elements of 1C and 2A tanks, and (b) subsequent operational openings in the roof of the arches of 1A after construction.

ii. There has also been non-structural damage to the tanks of the MHR in the form of (a) seepage and leakage at the roof level, (b) leaching of lime mortar, (c) delamination and damage of the wall plaster, and (d) delamination and damage of guniting or shotcreting around internal columns.

iii. Leakage of arches from the apex, red soil is seen, and grey colour is flowing of pointing material from the apex of the brick arches of 1A.

iv. There are considerable-sized tree roots in the walls of tanks 1A, 1B, and 1C. These roots inside are creating cracks, allowing for easy water seepage and leakage.

v. There are silt and clay deposits to a depth of 1 to 2 feet at several locations in all five tanks of the MHR. This indicates that no periodic cleaning to remove the silt deposited inside the tanks was carried out.

vi. The ventilation for the escape of residual chlorine was observed to be inadequate.

vii. All the outlet pipes and structural steel staircases of the tanks were observed to be severely corroded or scaled.

viii. The tanks 1B and 1C have a lesser usable capacity because of the volume occupied by the water treatment filtration units within them.

5. BASIC HYDRAULIC STUDY OF MHR

5.1 Visual Inspection of MHR from a Hydraulic Structure Point of View

i. Even though structurally the MHR consists of five tanks (compartments), 1A, 1B, 1C, 2A, and 2B, hydraulically it is only two tanks. It has been found that the inflow and outflow can only be made from 1A and 2A tanks.

ii. Tanks 1A, 1B, and 1C act as a single tank since the outflow pipes are located in Tank 1A. These three tanks are hydraulically connected for the flow of water from one tank to another through the openings of earlier sand filter units. During the period of repair in any one of these tanks, no water can be drawn from this group. Thus, during the repair for uninterrupted water supply, an alternative tank with a usable capacity equal to the usable capacity of all three tanks (i.e., 1A, 1B, and 1C) is required. The present usable storage of 1A, 1B, and 1C tanks combined is 35.35 ML (as per the record provided by BMC). It is worth mentioning that tanks 1B and 1C may have a lesser usable capacity than the one presented by BMC because of the volume occupied by the water treatment filtration units within them.

iii. Tanks 2A and 2B act as a single tank since the outflow pipes are located in Tank 2A. They are hydraulically connected through a single, large arch opening. These two tanks can be hydraulically disconnected, but there is no advantage since, during the repair of Tank 2A, water cannot be drawn from Tank 2B as there is an outlet from 2A only. Thus, during the repair for uninterrupted water supply, an alternative tank with a usable capacity equal to the usable capacity of tanks 2A and 2B is required. The present usable storage of tanks 2A and 2B combined is 39.17 ML (as per the record provided by BMC).

iv. Technically, usable storage is the storage available above the minimum drawdown level. The minimum drawdown level is the level below which the water cannot be drawn due to (a) the hydraulic head

available above the outlet pipe being insufficient to cause gravity flow in the pipes even to the nearest demand point and (b) the water level in the tank dropping below the outlet pipe level (outlet pipe is exposed to atmospheric pressure, leading to the entry of air and subsequent problems).

5.2 The Operational Timings of the Water Supply from MHR

The existing pattern of supply shows that the MHR is working 24 hours a day. All zones receive water only for one and a half to three hours a day with different staggered supply timings, except for the military area (24-hour supply), Peddar Road (7 hours), and Altamount Zone (7 hours). These operational timings indicate that the MHR is not available for repair without disturbance in the water supply.

It is worth cautioning that human entry for repair with water inside the MHR should be ruled out; even with full suit sanitization, repair with floating barges and under water repairs is also not at all accepted, and it involves the highest risk. If construction material spills into water, the drowning of any worker or the death of a worker due to suffocation may lead to further complications.

i. For cleaning the tanks, CPHEEO (2023, Part A, and Part B) recommended to "Make alternate arrangements for water supply to consumers served by the reservoir". This should also hold good for any type of repair inside the tanks. In the CPHEEO (2023, Part B) manual, it is mentioned that BMC has used underwater robots for silt removal, which may not be possible for repairs. Since silt is removed by sucking action, in repair, one can expect material to fall into the water if the tank is not emptied.

ii. An alternative tank with a usable capacity based on the hydraulic study shall be in place before starting the cleaning or repair work.

iii. Since both tanks Group 1 (having tanks 1A, 1B, and 1C) and Group 2 (having tanks 2A and 2B) cannot be cleaned or repaired at the same time, the usable capacity of the alternative tank must

be the maximum usable capacity of either group 1A, 1B, 1C (35.35 ML) or group 2A, 2B tanks (39.17 ML).

5.3 Hydraulic Analysis of MHR Based on Hydraulic Particulars Provided by BMC

5.3.1 Water Inflow and Outflow Patterns

The inflow and outflow patterns of MHR based on the data given by BMC are given in Figure 5.1.

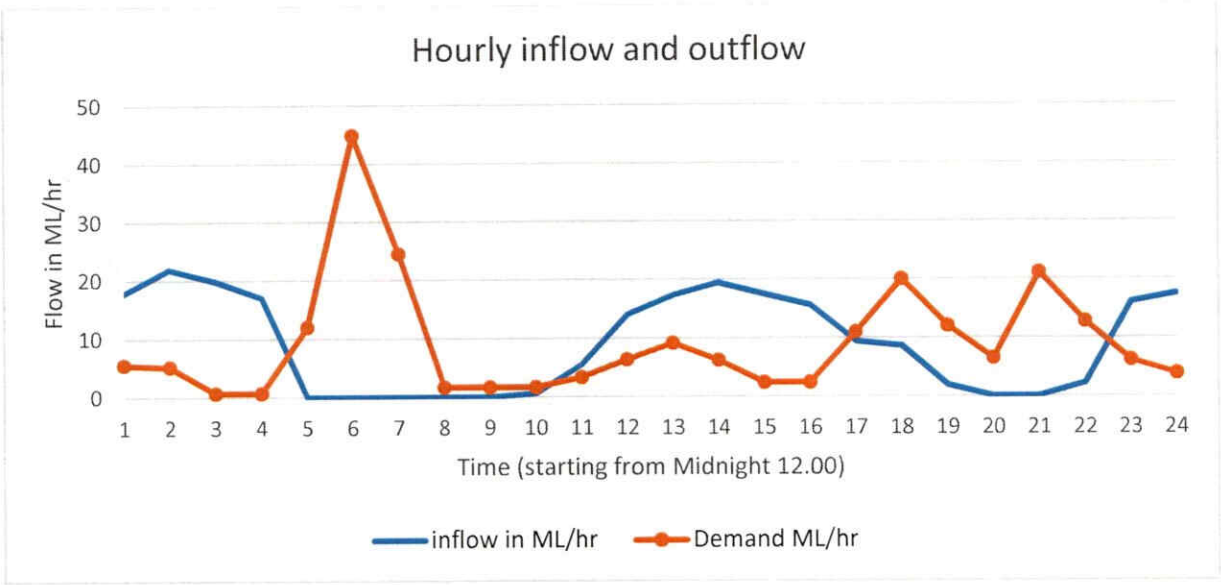

Figure 5.1. Inflow and outflow pattern of MHR (data Source: BMC)

From Figure 5.1, it is seen that the inflow pattern follows two cycles per day, starting from the previous day's night 9.00 pm to the current day 5.00 am, and then again from 10.00 am to 8.00 pm, with no inflow from 5.00 am to 10.00 am. The peak inflow is at 2.00 am and 2.00 pm during the first and second cycles, respectively.

From Figure 5.1, it can be seen that the outflow is continuous throughout the day and has two high outflow cycles: the first cycle starts from 4.00 am to 8.00 am, and the second cycle starts from 10.00 am to the next day at 3.00 am with multiple peaks. This is due to the staggered outflow operations of multiple outlets.

i. If there is any change in the inflow and outflow patterns, there will be a disturbance in the supply of water across the zones served by MHR.

ii. These patterns are linked with the supply reservoir (MBR) of the Bhandup water treatment plant and the demand for drinking water from various zones served by MHR.

5.3.2 Calculation of the Usable Storage Requirement of MHR for the Present Scenario

The usable storage capacity required for the present inflow and outflow patterns is estimated using the double mass curve technique as per CPHEEO (2023, Part A). The double mass curve drawn for MHR with an operational period of one day (i.e., the operational inflow-outflow cycle repeats every 24 hours), is given in Figure 5.2. From Figure 5.2, the maximum surplus in a day and the maximum deficit in a day account for the required usable storage of MHR. Based on the CPHEEO recommendations, the required usable storage of MHR for the given inflow and outflow patterns is given in Table 5.1.

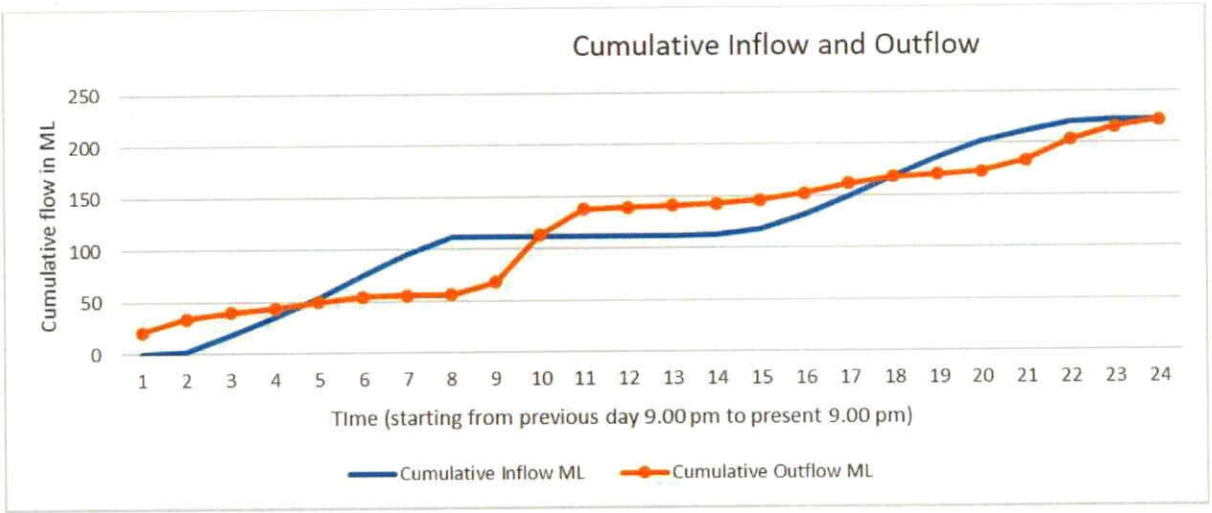

Figure 5.2. The mass curve of cumulative inflow and outflow of MHR

Table 5.1. Estimation of Usable Storage of the MHR

Time (hrs)	Inflow (ML/hr)	Outflow (ML/hr)	Cumulative Inflow (ML)	Cumulative Outflow (ML)	Difference between cumulative inflow and outflow (ML)
21	0	21.11	0	21.11	-21.11
22	2.1	12.74	2.1	33.85	**-31.75**
23	16	6.12	18.1	39.97	-21.87
24	17.4	3.83	35.5	43.8	-8.3
1	17.8	5.61	53.3	49.41	3.89
2	21.9	5.25	75.2	54.66	20.54
3	19.9	0.75	95.1	55.41	39.69
4	17.1	0.75	112.2	56.16	**56.04**
5	0	12	112.2	68.16	44.04
6	0	44.89	112.2	113.05	-0.85
7	0	24.52	112.2	137.57	-25.37
8	0	1.67	112.2	139.24	-27.04
9	0	1.67	112.2	140.91	-28.71
10	0.6	1.67	112.8	142.58	-29.78
11	5.5	3.34	118.3	145.92	-27.62
12	14	6.37	132.3	152.29	-19.99
13	17.3	9.17	149.6	161.46	-11.86
14	19.4	6.2	169	167.66	1.34
15	17.5	2.41	186.5	170.07	16.43
16	15.6	2.41	202.1	172.48	29.62
17	9.4	10.99	211.5	183.47	28.03
18	8.6	19.99	220.1	203.46	16.64
19	1.9	12.05	222	215.51	6.49
20	0	6.47	222	221.98	0.02
("+" indicates a surplus, and "–" indicates a deficit)					

As per the CPHEEO (2023 Part A) Chapter 12, Section 12.4.1. (an example is also given in Annexure 12.1 of the Manual).

The usable storage required = Maximum surplus + Maximum deficit

Based on the above method, the usable storage capacity required in MHR for the present inflow and outflow patterns = 56.04+31.75 = **87.79** ML

As per the present inflow and outflow patterns, MHR requires a usable capacity of **87.79 ML** to meet the demand. From the given hydraulic particulars of the MHR provided by BMC, it is seen that the present usable capacity is 74.52 ML, which concludes that the present usable storage capacity is a deficit capacity to the tune of **13.27 ML**.

It is concluded that while designing the alternative storage tank, this deficit of **13.27 ML** usable capacity shall be added to make the distribution of water even to the far-end people served by MHR.

Thus, the usable storage capacity of the alternative tank = 39.17+13.27=52.44 ML

Hence, based on the data made available to the committee and subsequent double mass curve calculations, the required usable storage capacity of the alternative tank shall be **52.44 ML**.

5.4 References

- *CPHEEO (2023) Manual on Water Supply and Treatment Systems, (Drink from Tap) Part A, Engineering-Planning, Design and Implementation, Fourth Edition, (Chapter 12, SERVICE RESERVOIRS & DISTRIBUTION SYSTEM), Central Public Health & Environmental Engineering Organization, Ministry of Housing and Urban Affairs, Government of India, New Delhi. https://mohua.gov.in https://cpheeo.gov.in*
- *CPHEEO (2023) Manual on Water Supply and Treatment Systems, (Drink from Tap) Part B, Operation and Maintenance, Second Edition, (Chapter 6, RAW WATER AND CLEAR WATER RESERVOIRS), Central Public Health & Environmental Engineering Organization, Ministry of Housing and Urban Affairs, Government of India, New Delhi. https://mohua.gov.in https://cpheeo.gov.in*
- *CPHEEO (2005) Manual on Operation and Maintenance of Water Supply Systems, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, and World Health Organisation, New Delhi. https://sswm.info/sites/default/files/reference_attachments/CPHEEO%202005%20Operation%20and%20Maintenance%20of%20Water%20Supply%20Systems.pdf*
- *CPHEEO (1999) Manual on Water Supply and Treatment, Third Edition, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, New Delhi.*

6. Conclusions and Recommendations

ToR 1: Whether the repairing of the existing Malabar Hill Reservoir is feasible without constructing a new alternative and without affecting the water supply from the MHR.

The visual inspection of the tanks of the MHR indicated structural damage (i.e., corrosion of steel reinforcement and spalling of the concrete cover of the RCC elements of 1C and 2A tanks, subsequent operational openings in the roof of the arches of 1A after construction) as well as non-structural damage (i.e., seepage and leakage at the roof level, leaching of lime mortar, delamination and damage of the wall plaster, delamination and damage of

guniting/shotcreting around internal columns, etc.), implying that these damages shall be repaired at the earliest convenience. To carry out the above repairs in an effective manner, the tanks need to be in empty condition. Currently, the MHR is being utilized to its maximum usable capacity, as a result, the repair of the tanks by making them empty will seriously disrupt the water supply.

At present, the water supply has a deficit of usable storage of 13.27 ML for the present inflow and outflow patterns of MHR. As per the CPHEEO manuals, an alternative arrangement should be in place before emptying the service reservoirs, which ensures an uninterrupted water supply. For the present condition of non-isolation of the individual tanks (compartments), the required usable capacity of the alternative tank is 52.44 ML (including the current deficit of usable storage).

The repairs to the existing tanks of the MHR cannot be carried out without emptying tanks and the construction of a new tank/reservoir. This additional tank will take care of the undisturbed water supply during the repair of MHR, close during periodic maintenance, and meet the deficit in water supply.

ToR 2: Whether phase-wise reconstruction of the Malabar Hill Reservoir is feasible without affecting the water supply from the MHR? This has zero tolerance i.e. no compromise to disturbance of the water supply to citizens from MHR.

Because of the facts mentioned in the response to ToR point 1, the phase-wise repair or reconstruction of the tanks of the MHR is not possible without affecting the water supply until a new tank / reservoir of the requisite capacity is constructed.

ToR 3, and ToR 4 Opinion on the public suggestions/objections from the local citizens, public representatives/experts

In total, 145 suggestion emails were received during the prescribed period by BMC. The public's overall suggestions are not to demolish the existing MHR, not to cut down trees, or reduce the number of affected trees. While creating the required capacity to undergo effective repair or reconstruction, BMC shall plan the new facility in such a way that it will affect a minimum number of

trees. These suggestions were critically reviewed and duly considered in the present recommendations.

ToR 5. The time period for study and to give opinion will be one month only

Every problem, depending on its importance, requires a minimum period to understand, analyze, and find a permanent, acceptable-at-large, and implementable solution by a committee. Getting a solution for the current issues of MHR requires more time because of its complexity, age of the system, and interconnections with the environment; hence, there is a delay in the time period of the present study.

ToR.6 IIT Bombay may suggest any other actionable proposal, if any

To the best of our knowledge, the Mumbai water supply scheme is one of the best planned, designed, executed, and operated systems in the category of gravity flow water supply systems, having served for more than 100 years. The BMC should be proud and prepare a master plan to maintain this as per the standards of CPHEEO (2005) and as a functional heritage water supply system. Currently, MHR serves potable drinking water to a population of around 18 lakhs. Given the above, the following are strongly suggested and recommended, and shall be carried out in the order or sequence listed below for MHR:

1. As an immediate short-term measure, the cleaning of the tanks as per the CPHEEO (2005) manual shall be taken up on a priority basis. This includes desilting, the removal of roots inside the tank walls and the roots of large garden plants on the top, and the removal of rust from pipes and structural steel staircases.
2. Construct a new alternative tank with a usable capacity of 52.44 ML with the required hydraulic head in conjunction with the present hydraulic head of MHR for uninterrupted gravity flow water supply. The new alternative tank should preferably be constructed on the land reserved for the hydraulic facility, and being on the hill site, the BMC shall carry out a proper geological investigation, and the design of the tank shall be accordingly carried out with proper safety measures.

3. Empty either interconnected 1A, 1B, and 1C tanks or interconnected 2A and 2B tanks at a time after the construction of the alternative tank. The suggested works cited below in points 4 to 8 shall be carried out under empty tank conditions.
4. As the existing tanks are more than 100 years old and currently have structural and non-structural damage, a scientific structural and hydraulic audit of the tanks shall be carried out.
5. A rigorous visual inspection of the tanks shall be carried out to assess the structural damages. In addition, the hydraulic conditional assessment of the pipes and valves of the MHR tanks shall be performed.
6. Non-destructive testing of the structural elements of the tanks shall be carried out.
7. Destructive testing of the materials of tanks (i.e., through extraction of the concrete cores, lime mortars, bricks, etc.) shall be carried out.
8. Load tests on the roof of the tanks shall be performed to assess the present load-carrying capacity as well as the inherent elasticity.
9. Analytical models of the tanks shall be made, and the maximum stress level in the elements shall be worked out.
10. The seismic safety of the existing tanks to current codal requirements shall be assessed.
11. Based on the outcome of the above, a decision to either repair or reconstruct the existing tanks of MHR shall be taken up.

Prof R S Jangid

Prof V. Jothiprakash

Prof Dasaka Murty

Shri C H Kandalkar

SHIRISH PATEL & ASSOCIATES
CONSULTANTS PRIVATE LIMITED

23 February 2024

Shri. P.B. Bandgar
Chief Engineer, (Water Supply Projects),
Mumbai

Subject: Committee to Review Reconstruction Work of Malabar Hill Reservoir- Final Report

Dear Sir,

Please find enclosed the Final Report on the above-mentioned subject by the Committee constituted by the Hon'ble Municipal Commissioner. Kindly note that the report has two parts. The enclosed report constitutes one part which has been prepared jointly by Committee members Prof Alok Goyal of IIT Bombay, Er. Alpa Sheth, Ar Rahul Kadri and the undersigned Dr V. Nori.

With thanks and best regards,

Dr. V. V. Nori,
Chairman

Cc: Shri Mangal Prabhat Lodha, Guardian Minister, Mumbai

बृहन्मुंबई महानगरपालिका
पाणी पुरवठा प्रकल्प
प्रमुख अभियंता यांचे कार्यालय
27 FEB 2024
प्र.अ./पा.पु.प्र./स्विय/ 4857

प्र.अभि. / पा.पु.प्र. / स्वीय / 4857
29 FEB 2024
Dy CHE (WSP) P&D
For favour of
28/2/24
Chief Engineer
(WSP)

Dabur House (Formerly Balsara House) 3rd Floor 41-45 Nagindas Master Road Mumbai 400 001 Tel: 91-22-2265-5039, 2263-0193
CIN:U74140MH1976PTC018775 Email: spa@spacpl.com or spacpl@gmail.com Webiste: www.spacpl.com

FINAL REPORT OF THE COMMITTEE FOR REVIEW OF MALABAR HILL RESERVOIR

20 February 2024

BACKGROUND:

MCGM had proposed a project to reconstruct the Malabar Hill Reservoir in a phased manner (with an additional capacity tank of 15 ML for storage during the construction of phases) and the project was tendered out and the Contractor was selected. The total project cost was approx. Rs 280 crores. The Contractor subsequently expressed his inability to reconstruct the Reservoir in a phased manner and after many deliberations, modifications, and iterations the project became a completely new project that included the full demolition of the existing Reservoir, most of which is over 135 years old, and construction of a much larger Reservoir with an additional capacity of 91 million litres at a new projected cost of approx. Rs 700 crores. The new proposal of the Contractor, accepted by MCGM, required a larger footprint, cutting of 189 trees and replanting two hundred trees, and the non-functionality of the Hanging Gardens which rested on top of the Reservoir for several years.

Based on a public request from residents, environmentalists, and technical experts for an alternative to the extensive demolition and reconstruction, Hon Municipal Commissioner constituted a Committee of Professors from IIT Bombay (Professor Alok Goyal (Str. Engg.), Prof. R S Jangid (Str. Engg.), Prof V Jothiprakash (Hydraulics), Prof Dasaka Murthy (Geo-technical)), Architect Rahul Kadri, Dr V V Nori (Str. Engg.), Er. Alpa Sheth (Str. Engg.) and DMC (Special Engineering) Mr C H Kandalkar.

SCOPE OF COMMITTEE:

The scope of work was defined as under:

i. Possibility of Repairing the existing Malabar Hill Reservoir without the construction of a new Reservoir and without affecting the water supply from MHR.
ii. Possibility of phase-wise repair without affecting water supply from MHR.
iii. To study and opine on suggestions from residents and public representatives.
iv. Any other suggestions for actionable proposals?

COMMITTEE MEETING AND SITE VISITS

The committee has held two virtual meetings. The first meeting was held on November 21, 2023 (with full attendance except for DMC) and the second meeting (full attendance of Committee) was held on December 19, 2023. Minutes of the first meeting are attached. This interim report includes the discussions of the second meeting.

Site visits for Compartments 2A and 2B were conducted on December 7th (All in attendance except Ar. Kadri and Prof Alok Goyal who had a very extensive visit to the Reservoir earlier in his capacity as Consultant to MCGM) and Visit for 1A, 1B and 1C was held on December 18, 2023 (All in attendance except Prof Alok Goyal for the above-mentioned reason).

REMARKS BASED ON THE SITE INSPECTIONS

Most of the reservoir is built in brick and stone masonry in lime mortar and Plain Cement Concrete (PCC- without reinforcing steel) and is in excellent condition. The walls are in random rubble stone masonry.

- The walls appear to have been gunited/shotcreted a few years later with no reinforcement, possibly as a waterproofing measure.
- In reservoir 1C, a small part of the roof appears to be a later addition and is constructed in reinforced concrete. The reinforcing steel in these vaulted roofs has corroded at some locations, mostly along the perimeter bay. The rest of the roof is in vaulted plain cement concrete. A few internal panels which appear to have been gunited subsequently show some corrosion of expanded weld mesh which was placed before guniting. The reinforcing steel is redundant as the arches/vaults are in compression and hence despite the corrosion, the small, affected area of the structure is not in any danger of imminent collapse. However, as and when the repairs can be carried out, the corrosion should be attended to. The repairs should be carried out sensitively and sensibly with compatible material that will not react with chlorine. Options need to be studied for durability and longevity after understanding the structural system and the need for additional intervention.
- A small portion of Tank 2A roof which was added later in RCC shows some signs of corrosion under the commissioner's bungalow. The affected area is approx. 35'x100' or 350 m2 in total 2A area of 7906 m2 constitutes less than 4.5% of the overall roof area of the tank.
- In all the tanks, minor evidence of past leakage was noticed. Brown mud stains and white effervescence stains were seen on the crest of the arch or towards the top. No damage was visible to the brick or concrete and they both appeared to be in excellent condition.
- At two locations in tank 1A, small roots were observed to have creeped into the tank. Most of the wall surface was without leakage or the presence of roots.
- In tank 2A, in small portions delamination of the wall plaster was noticed. No structural damage or cracks or any signs of distress were noticed on any of the walls, even behind the delamination.

CONCLUSION (PHYSICAL MEETING HELD AT IITB CONFERENCE ROOM 111 ON 17 JANUARY 2004)

1. It must be emphasised that the observations based on visual inspection may not be comprehensive. For example, it was not possible to inspect the parts of the floors where the water was knee-deep with silt. Some apprehensions have been raised regarding water leakage through the floor. Considering that the reservoir caters to the supply of potable water to lakhs of people, thermal imaging techniques may be used to identify any areas of distress or weakness (which were not observed by the committee) in the structure accurately. It is important to prepare as built drawings of the reservoir, with grids numbered that will facilitate recording observations, defects and all other matters that pertains to details of construction.
2. The Reservoir is in good structural condition and does not require demolition or reconstruction in the next 10-15 years as there is no danger of collapse disrupting the water supply. No structural distress (in the form of cracks or deformation) was observed in any of the five compartments of the reservoir. This conclusion of the structural engineering experts in the committee is based on the limited (feasible) visual inspection. A detailed engineering inspection of the Reservoir may be planned by MCGM in the coming years under operational conditions without disrupting the water supply. As abundant caution, however, we suggest that the tanks should be inspected annually, and a detailed inspection report prepared.
3. To extend the life beyond 10-15 years, MCGM may plan repairs of the roof (RC part of the roof, covering a small area). It may be possible to repair or replace the roof showing signs of corrosion of reinforcing steel when all parts or major parts of reservoir remain operational. The repairs need to be carried out at a slow pace (few hours available with low water level) and will require special arrangements (e.g. stainless-steel form work, trained workers in clean

suits and other such special requirements). Ideal situation for water supply will be that repairs are done in the operational conditions of the reservoir.

4. In the masonry structure with garden on the roof, water seepage has been noticed at few places. Seepage has not created any structural problem as no displaced bricks or visible cracks in masonry could be observed. Additionally, MCGM has not yet reported any contamination of water due to seepage. However, it is recommended that (1) MCGM maintain a tight vigil on the quality of water, especially in the rainy season, by increasing the frequency of water quality testing, and (2) plan desilting of tanks (can be done without stopping the operation of the reservoir). If the test data of water indicates unacceptable contamination of water due to seepage, corrective measures may be taken by waterproofing the slab from above to block the entry of water from the roof.
5. The possibility of repairing the roofs of tanks without emptying needs to be explored in depth. Since we are dealing with potable water one should ensure that there is no contamination. The working platforms should be suitably enclosed, and the works monitored by a competent supervisor.
6. As regards the geo-technical stability, it gets compromised when any new constructions are undertaken without ensuring the stability of the existing structures by construction of earth retention structures.
7. There is an urgent need to formalise an inspection and maintenance manual. The frequency of inspection may be increased slowly based on feedback from earlier inspections. There is an urgent need to refurbish access stairs and strengthen the existing openings in the roof.
8. There should be a contingency plan for a standby reservoir of suitable capacity that avoids uprooting old trees. This can be done by mapping the area and locating such trees. The old building near the pump house needs to be replaced/ retrofitted as decided by BMC.
9. The current system of MHR is a classic example of a water supply system having a minimal carbon footprint in case of a gravity water supply to such a large population. It is therefore important to maintain the existing system with minimum intervention. In the coming 2-3 years, MCGM should develop a maintenance scheme for the continuous use of the present reservoir.
10. These minimum interventions will allow for continued use of the reservoir for a long time.

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