Maintainenace of Hydraulic Structures - Some Case Studies

S. K. Mazumder
Former AICTE Emeritus Professor of Civil Engineering
Delhi College of Engineering/ Delhi Technology University

1. Introduction

After independence, India has grown its infrastructures all over the country e.g. roads, railways, metros, tunnels, bridges, buildings, dams, barrages, canals, heavy industries, ports, airports etc. through successive Five Year Plans. All these infrastructures, built at enormous costs, need annual/ periodic maintenance in order that they perform as planned with a view to extend their life for providing proper service to the Nation. Residual life and performance of all infrastructures depend not only on proper planning, design, quality of construction and construction materials, but also on proper maintenance so that they continue to serve the purpose for which they are built. There are several instances where it is noticed that a large amount of public money is invested in creation of infrastructures but they are not used efficiently and are not properly maintained, thereby drastically reducing their life as well as return commensurate with the investment. Thus, the question that arises is - Should the country build infrastructures which cannot be maintained? In this paper, some of these issues are discussed with reference to a few hydraulic structures like dams, weirs and barrages, canals anal structures, roads and cross-drainage structures like bridges and culverts and flood embankments.

2. Performance and Maintenance of Hydraulic Structures

Unlike buildings where there are a lot of private investments, most of the hydraulic structures are constructed, operated and maintained by the government- both Central and the States. People in general don't take interest in these properties since they consider the public properties as not belonging to them and there is hardly any public participation in the operation and maintenance of these structures often resulting in their poor performance. Some of these issues are discussed sections 2.1 to 2.6 in the paper.

2.1 Dams

More than 6000 dams (GOI, 2019) – high, medium and small -have been constructed all over the country. Dams which are classified as rigid masonry dams may be of gravity type, arch type or buttress type. Flexible dams are built with earth and rocks. Rubber dams (inflatable ones) can be built for heading up of water during lean flow period and removed during flood season. The main purpose of dams is to store water during monsoon for the purpose of water supply during lean season and drought period. Dams are also used for flood control and hydro-power generation. Rigid concrete or masonry dams need less maintenance compared to flexible ones. However, water seeping through innumerable joints and inspection galleries pose a lot of problems unless inspected, repaired and maintained properly. Besides loss of water, seeping water may cause structural problems which requires constant vigil and regular corrective measures.

Rigid dams, if overtopped due to inadequate spillway capacity, may not fail. These are designed as earthquake resistant structures. Flexible dams, on the other hand, would fail due to overtopping. Failure may take place also due to uncontrolled seepage resulting in piping and sand boiling, undue and differential settlement, cracks, flood erosion, slope failure, burrowing of animals, etc. They need constant attention and maintenance. There are several instances of wash out of flexible dams causing flood damages downstream.

One of the major concerns in all dams is silting of reservoir and loss of live storage capacity (Deepa, 2015; Mazumder,2016; CBIP,1980,) associated with loss of water supply initially promised. Flushing of sediments may restore some capacity and dredging to remove sediments is highly costly.

2.2 Weirs and Barrages

These are low height obstructions usually provided for flow diversion. Innumerable weirs and barrages have been built all over the country for irrigation, drinking water, navigation, hydro-power, etc. Barrages are invariably provided with gates for heading up of water level in all run-off the river schemes for hydropower generation. A Typical barrage section is shown in Figure-1 illustrating different components e.g. spillways, gates, piers etc. for diversion of flow to head and tail race canals/ tunnels, desilting units, power house, etc. All these components need regular maintenance for efficient operation and for increasing life span. Spillways, energy dissipaters, tunnel linings, turbines, gates. piers, etc. are often damaged due to rolling sands, stones, debris, etc. carried by the flowing water. In case of Kosi and Farakka barrages there is severe problem of bank erosion and threat of flow avulsion. Huge amount of money has to be spent for river training in both Kosi and Farakka barrages (Mazumder,2004; Chitale,2009; CBIP,1992) for their safety.

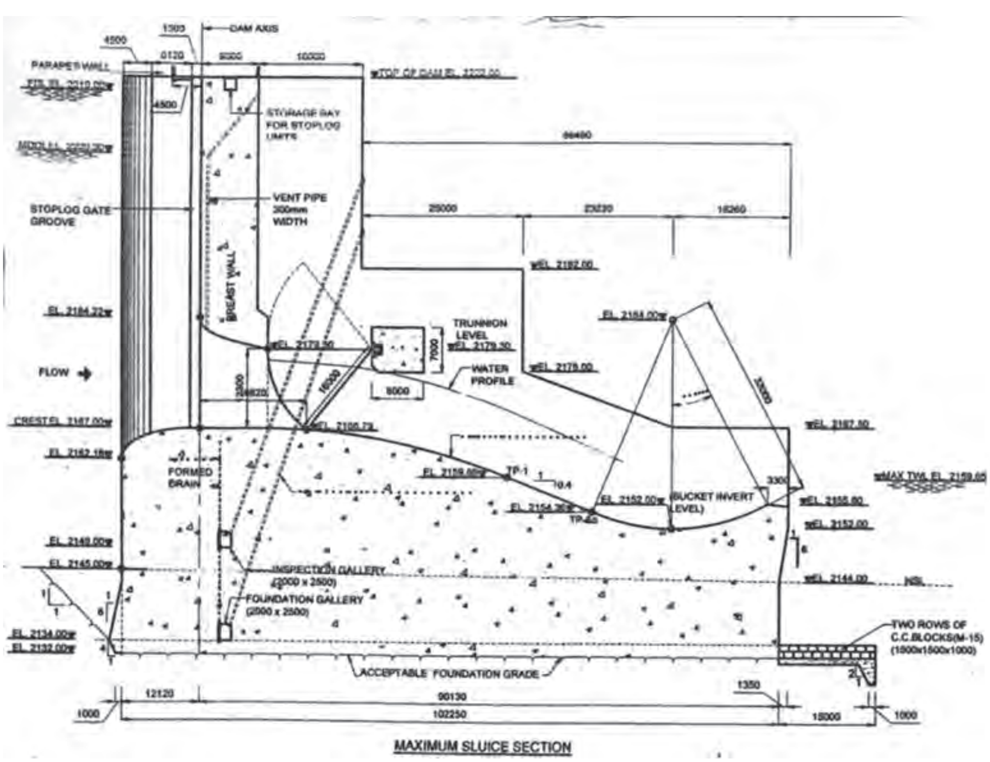


Figure-1: Showing a Low Head Barrage with Piers, Gates, Galleries and Spillway

2.3 Canals and Canal Structures

After partition of India, most of the canals built in pre-independence years went to Pakistan, except the Ganga Canal and few others. Government of India built numerous multi-purpose projects with canal networks -mains, branches, distributaries, water courses, field channels, escapes, drainage channels, etc. A large numbers of canal structures e.g. aqueducts, siphons, regulators, drops, flow meters, silt ejectors, escapes etc. were to be built for conveying, operating and distributing irrigation water to the agricultural farms and disposal of excess water. Some of the canals are lined, however, a majority of them especially the mains and the branches are unlined because of their large size. There is thus huge loss of water (Bharat Singh,1991; CWC,2010, Mazumder,2016) in conveyance due to poor maintenance of the canals.

During the British period, 85% of the annual maintenance cost of canals used to be realised from irrigation revenues. Today, the revenue earned is so poor (due to the Government policy of free water and electricity supply) that hardly 15% of maintenance cost can be met from revenue earned (Mohile,1994), leave apart the cost of operation, administration and interest payable to borrowers. It is estimated that 20 to 30% of irrigation water is lost (Mazumder,1986; Mazumder and Kumar,2015) in conveyance and about 10% in evaporation from open canals. The other mode of water transport through closed underground pipe systems to minimise the water loss is a costly proposition. One of the fundamental reasons for the current state of affair is lack of participation and involvement of farmers who think that the canals are Government properties and the owner is responsible for their maintenance. This has resulted in poor performance, loss in carrying capacity due to silting and scouring, weed growth, etc. in the canals. Timely supply of canal water, in required quantities, equitably distributed amongst farmers needs a lot of co-ordination and public participation.

2.4 Roads

Design life of a road is drastically reduced due to lack of proper maintenance. Cracks, pot holes and other distresses are often observed in road pavements resulting in poor riding quality, hydroplaning, slow speed, traffic congestion, etc. Erosion of shoulder is often found due to improper camber and not being paving the shoulder, as shown in Photograph-1. Photograph -2 shows cracks in a rigid concrete pavement.

One of the common problems often experienced in both urban and rural roads is inadequate drainage of surface water during rainy season due to accumulation of debris and silts in kerb inlets because of their improper location, spacing and size. Photpgraph-3 illustrates a hilly road in Mizoram where all the pavement materials was washed out and the base material was exposed due to inadequate drainage system and growth of weeds on shoulder obstructing free movement of surface run-off from the pavement as well as inadequate drains and size of drains to intercept the run-off from the uphill region. Most of the foot hill drains were blocked by debris and stones eroded from the adjoining hill reducing the conveying capacity of the drains.

Photograph-1: Damage to Road Shoulders

Photograph-2: Showing Crack in a rigid concrete pavement

Photograph-3: Washing out of Pavement in a Hilly Road in Mizoram due to Improper Drainage

Photograph-4: Weed Growth near Culvert Inlet in a road in Mizoram

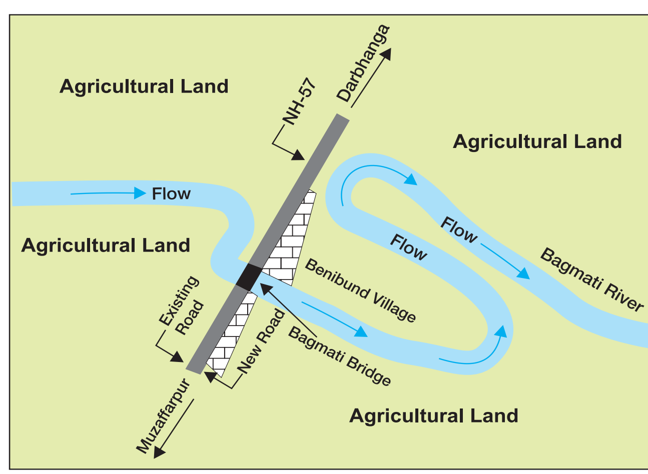
Another important reason of road subsidence and cracks on road surface is inadequacy of sub-surface drainage of water seeping from cracks, joints, pot holes, shoulders, etc. from top surface of the road. Capillary rise of ground water, unless intercepted by properly designed drainage layer, is responsible for loss of strength of the sub-grade. A layer of GSB must be placed below the drainage layer in order to arrest movement of fines from sub-grade to drainage layer thereby reducing its permeability and draining capacity.

2.5 Cross-Drainage Structures

Innumerable cross–drainage structures are to be built in both canals and roads for free movement of water without undue afflux and other associated problems. Inadequate cross drainage without proper planning and design often result in severe problems often resulting in their poor performance and reduction in the life of the canals and the roads.

Culverts are an integral part of roads. Unless properly planned, located, designed and maintained, their conveying capacity is drastically reduced. Photograph-4 illustrates the inlet condition of a typical culvert in a road in Mizoram. The inlet is blocked due to growth of weeds, grass, etc. and stones deposited near inlet. Most of the pipe culverts in a hilly road are pushed from a deep pit at the entrance. Unless the stones, silts and debris deposited in these pits and within the culverts are cleaned, their conveying capacity is reduced resulting in high afflux and submergence of approach road adjoining the culverts.

Bridges are to be provided over all stream crossings in roads, railways, canals, drains, etc. Any negligence in their structural design would cause incipient failure of the bridge when it is opened to traffic. Inadequacy in hydraulic and hydrologic design (Mazumder,2017) may not cause immediate failure but it would cause perennial problem of maintenance. Figures-2 and 3 illustrate a few typical cases of distresses observed by the author while



Photograph-5: Plan view of Bagmati River Showing Sharp Bends U/s and D/s of Bagmati Bridge on NH-31 in Bihar

Photograph-6: Formation of Bowls U/s and D/s of a Bridge on NH-57 in MP likely to be Outflanked due to Excessive Restriction of Waterway

working on projects. The approach roads were damaged. The problems arose due to inadequacy of waterway under the bridges constructed in wide flood plains. The cost of river training and maintenance may sometime exceed the cost of a bridge. Annual maintenance of the superstructure and foundation of a bridge is a must for safety and for extending the life of bridges.

2.6 Flood Embankments/ Levees

As per the "Rastriya Barh Ayog" report (1980), India built 5.300 km of flood embankments/ levees all over the country before 1954. After the extra-ordinary1954 flood, 16,000 km of levees were added by 1980. By the end of the XIIth Five Year Plan, the total length of levees built all over the country, was 37,062 km. These embankments/ levees protect both agricultural land and rural and urban properties. Flood protection measures consist of building dams, flow diversion, shifting of houses to a higher elevation, etc. (Mazumder et al,2018). However, the most effective measure for flood control to prevent damages is to construct flood embankments in areas susceptible to flood damage due to overtopping of river banks. They are also constructed upstream and downstream of barrages in the plains to contain afflux upstream and for the safety of the barrages e.g. Kosi barrage (Sanyal,1980), Farakka Barrage (Mazumder,2015), Gandak barrage, etc. The Brahmaputra River and its tributaries flowing through Assam, and the Ganga River and its branches flowing through UP, Bihar and West Bengal cause flood havoc almost every year due to the large volume of water flowing from their respective catchments. In all these states, flood embankments exist along river banks to protect areas affected by floods.

Levees are usually not built to the same stringent specifications like earthen dams which are built across the rivers. Hence, constant vigil and maintenance are needed to avoid failure of the embankments due to multiple reasons e.g. overtopping, sliding, erosion, settlement and cracks, inadequate sluices, burrowing by animals, etc. Embankments breach also by direct attack of river due to meandering and many other problems related to river behaviour and morphological changes in the river within the embanked reach, etc. Breaches in Kosi flood embankments (Mazumder,2011; Chitale,2009; Sanyal,1980) and afflux embankments have caused devastating floods resulting in loss of life and properties, communication problem, and unimaginable human sufferings – especially for poor people who live near river banks and flood plains (Photographs-5 and 6).

Photograph-5: Disastrous floods in Malda District in West Bengal due to breach in Marginal Flood Embankment U/S of Farakka Barrage in 1998

Photograph-6: Devastation brought about by flood of River Kosi due to change of its course after a breach in left Afflux Embankment in 2018

Flood embankments are owned and maintained mostly by Government and there is hardly any people participation in their maintenance. This is one of the major reasons of failure of embankments leading to breaches and floods. The other reason is lack of appropriate knowledge of river behavior and morphology of the river (Garde,2006). Failures of embankments are not properly investigated in India since the interest is generally more in construction rather than in maintenance. River training measures adopted are found to be not only highly costly but ineffective too due to inadequate investigations. Since most of the flood control measures are undertaken in a haste under emergent condition and a lot of money is involved in flood relief - the quantum of money actually used for the purpose is questionable.

3. Operation and Maintenance of Hydraulic Structures

Operation and Maintenance of hydraulic structures require knowledgeable, experienced and trained personnel, regular inspection, repairs and upkeep (Sheng-Hong Chen). Inspection implies the observation of the state of the structure, repair and restoration of the structure to its original state. Two main classes of maintenance are discerned: Corrective and Preventive Maintenance. When a Corrective Maintenance strategy is applied, the structure would be repaired after failure. In a Preventive Maintenance scheme, the structure would be repaired at specified intervals defined in time or operational hours before failure occurs. In a more refined strategy, the state of the structure is inspected at such intervals. On the basis of the inspection result, the decision to repair is taken.

Persons responsible for Operation and Maintenance of hydraulic structures must be conversant with the following:

- Standing Operating Procedure (SOP) and Operation Schedules,
- Maintenance and Vigilance procedure for the structure,
- Maintenance and Operation schedule for all control equipment,
- Identification of signs of deficient behaviour,
- Reporting procedures of Emergency Situations and Emergency Repairs,
- Training, updating and knowledge of personnel concerned
- Regular updating of relevant codes by BIS, IRC, etc.

Periodical Inspection of hydraulic structures is necessary specially before and after monsoon season to ascertain/ examine their condition and functioning. The main purposes of carrying out Periodic Inspection are:

a. to ensure adequacy of the structures to serve the purpose for which they were designed,

b. to verify the conditions of the structures and monitor their behavior,

c. to investigate conditions that might cause distress to the structures, and

d. to study the extent of deterioration based on which maintenance and repairs are to be done.

4. Agencies/ Stake Holders Involved in Operation and Maintenance

Usually, the owner of infrastructures is responsible for Operation and Maintenance. In most of the hydraulic structures discussed under section 2 above, the Government-both at the State and Central levels- are the owners and the responsibility of Operation and Maintenance lie with them. The Central Water Commission (CWC) under the Ministry of Jalshakti, Government of India has the responsibility of Operation and Maintenance of big dams (like Bhakra dam, Tehri dam, etc.) and big barrages (like Kosi barrage, Farakka barrage, etc.). Responsibility of Operation and Maintenance of the numerous medium and small dams and barrages owned by the State Governments lie with the respective States. Flood Embankments, except a few owned earlier by local Zamindars, are maintained by the States to which they belong to. The same is the case with canals and canal structures unless owned by private bodies like Jain Irrigation System, etc. In the road sector too, maintenance of National Highways and Expressways are carried out by NHAI, CPWD under the Ministry of Roads Transport and Highways, Government of India. However, majority of the State roads, District roads, Village roads, etc. lying within the jurisdiction of the States are maintained by the State Public Works Departments and other local bodies of the respective States. Canals and canal structures are usually operated and maintained by the Water Resources/ Irrigation Departments of the respective States except for centrally sponsored Government projects like Rajasthan canal, Bhakra Nangal canal, Hirakud canals, DVC canals, etc. owned by the Center. Cross-drainage structures like bridges and culverts are to be maintained by the authorities owning the roads. River training, however, is extremely costly and needs deep knowledge of river morphology. Depending on the river size and flow, the training works may be executed by either the State or the Central Government body like CWC.

5. Some Concluding Remarks

After Independence, India has invested a huge amount of public money in building numerous infrastructures for the prosperity and progress of the country. Initially, there were a lot of problems due to paucity of data, lack of proper planning, deficiency in design and construction, etc. Now the country possesses the knowledge and expertise in building almost all infrastructures needed for growth and development of the country. It is, however, extremely important that the infrastructures created must be protected, operated and maintained properly to get the returns, improve their performance and increase their life span as envisaged. Proper planning, design and construction are intimately related to recurring maintenance cost. In the domain of hydraulic structures discussed in this paper, there is an urgent need to further improve upon by updating knowledge and experience in order to achieve higher efficiency and better performance. The Operation and Maintenance manuals wherever developed, need to be implemented more effectively.

With the current technology available all structures can be remotely monitored 24x7 and their behaviour tracked and observed. Sensors can be programmed to raise alarms in case the behaviour crosses a threshold limit. Aerial monitoring can also be done and that would save a lot of time. Use of IoT must be enhanced to monitor, repair and maintain all the assets built for the development of the nation.

4. References

1. Bharat Singh (1991), “Management of Irrigation in India – A perspective” pub. in “Water Management” by Water Management Forum, The Institution of Engineers (India)

2. CBIP (1992)., "River Scour" Proc. of National Workshop on River Scour by Central Board of Irrigation and Power" held at Varanasi, 28-29 April 1992.

3. CBIP (1980), "Life of Reservoir", Technical Report No.19, pub. by Central Board of Irrigation and Power, Malcha Marg, Chanakyapuri, New Delhi, Sept.1980

4. CWC (2010) "Water Use Efficiency for Irrigation Projects"- `Pub. By central Water Commission, Min. of water Resources, River Development and Ganga Rejuvenation, Govt. of India, april,2010

5. Chitale, S. V. (2009) "Kosi Disaster-Caution and Pre-Caution" ISH J. of Hyd. Engg.Vol.15 No.1, March

6. Deepa S., Koomullil, U.C., Chaube and Ashish Pandey (2015), "Revisiting the useful life computation of Gobindsagar (Bhakra) reservoir", ISH Journal of Hydraulic Engineering

7. Garde (2006) "River Morphology", New Age Int. Pvt. Ltd, New Delhi

8. GOI (2019) "National Register of Large Dams -2019", Dam Safety Organisation, Central Water Commission, Ministry of Jalshakti, Government of India, New Delhi, June 2019

9. Mazumder, S. K., Dhillon, M.S. and Kanwal A. (2018) "River Action Plan, Flood Management & Basin Development"-Lead paper in a Souvenir "River Action Plan, Flood Management & Basin Development" published by Consulting Engineers Association of India, 27-28 July at Hotel Sangrila, New Delhi, pp.19-28

10. Mazumder, S. K. (2017) "Some hydrologic and hydraulic aspects of planning and design of road bridges" pub. in Journal of 'the IB&SE Volume 47 Number 1 March 2017 pp 103-111

11. Mazumder, S. K. (2016) "Discussion of Revisiting the useful life computation of Gobindsagar Bhakra reservoir by Deepa S Koomullil, U C Chaube and Ashish Pandey" pub. in ISH J. of HYD Engineering V

12. Mazumder S.K. (2016) "Post-Independence Scenario in Irrigation Sector-Need for Private Participation" in the Annual Technical volume (2015-16) on "Traditional Irrigation Systems in India" pub. by the Civil Engg. Divn. Board of IE (I).

13. Mazumder S. K. (2015) "River Morphology, Flood Erosion and Protective Works for Farakka Barrage on River Ganga", National Conference on Ganga Rejuvenation, org. by National Institute of Hydrology (NIH), Ministry of Water Resources, Government. of India, at NIH - Roorkee, Dec. 16-17.

14. Mazumder S. K. and L. V. Kumar (2015) "IRRIGATION MANAGEMENT BY LOSS REDUCTION, RECYCLING AND WATER TRANSFER" pub. in the Proceedings of National Conference on 'Challenges in Irrigation Mgt. for Food Security', org. jointly by IWRS (Indian Water Resources Society, Roorkee), Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, and Jain Irrigation Systems during Dec. 26-27.

15. Mazumder, S. K. (2011) "Breaching of Flood Embankments with Particular Reference to Kosi & Farakka Barrages in India" paper pub. in the Journal of Water Energy International by Central Board of Irrigation & Power, New Delhi, March 2011

16. Mazumder, S. K. (2008), "River Behaviour near Bridges with Restricted Waterway and Afflux- Some Case Study" Paper pub. in Indian Highways. Vo.37, No10, Oct 2009.

17. Mazumder, S. K. (2004) "Analysis and Control of Erosion of River Ganga Upstream and Downstream of Farakka Barrage" by MOWR, CWC & CWPRS, 12-13 Feb. 2004, New Delhi

18. Mazumder, S. K. (1986) "Efficiency of Irrigation in some River Valley Projects in India" Proc. of International Seminar on Water Management in Arid and Semi-Arid Zones, held at Hissar Agricultural University, Haryana, Nov. 25-27, 1986.

19. Mohile, A. D., Subhas, C., and Singh, S.N. (1994) "Financial performance of major and medium irrigation projects" Proc., Fifth National Water Convention, Org. by National Water Development Agency, Ministry of Water Resources, Government of India, Faridabad (Haryana), Feb 25–27. doi:10.3168/jds. S0022- 0302(94)77044-2

20. Sheng-Hong Chen "Operation and Maintenance of Hydraulic Structures" A. T.B. Publisher: Springer, Berlin

21. Rastriya Barh Ayog (1980) A Report published by National Commissions on Flood, Vol. I &II.

22. Sanyal, N, (1980) "Effect of Embankment of River Kosi" Proc. Int. Workshop on 'Alluvial Rivers' organised by Univ. of Roorkee, March 18-20.