

Assessment of Selected Dams in Kwara State, Nigeria

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Abstract

In Nigeria, more than 50% of the geographical area lies in the Savannah. Over time, this area has been vulnerable to the vagaries of periodic and severe droughts, affecting the survival of man and animals. Safe and economic design and construction of dams to store surplus river waters thus assumed greater urgency. However, dam failures and flood issues has caused catastrophic damages and losses of lives and properties. The uncertainties associated with deteriorating dams have necessitated proper and timely assessment and rehabilitation of these structures. This study identifies and investigates relapse in four (4) selected dams in Kwara State namely: Unilorin-, Maletе-, Okuta-Oja- and Asa-dam. A series of field inspection was carried out and results obtained were analyzed. Amongst the four dams, Okuta-Oja dam displayed the worst case of relapse with seepages through the foundation and body of the dam. About 20 baffle blocks out of 30 have been damaged in Unilorin dam, while Maletе dam was undergoing re-construction owing to seepage failure. Asa dam however remains intact with no physical and structural defect. Unless appropriately handled, ageing and relapsing infrastructural systems can pose a significant problem, threatening economic prosperity and public safety. Thus, monitoring the state of dam structures to ensure timely maintenance is critically important to preventing catastrophic disasters.

Keywords

Dam, Relapse, Assessment, Seepage, Breach, Failure

1. Introduction and Concept

In Nigeria, more than 50% of the geographical area lies in the Savannah and over time, this area has been vulnerable to the vagaries of periodic and severe droughts, affecting the survival of man and animals (Adeniji, 2003). Safe and

economic design and construction of dams to store surplus river waters thus assumed greater urgency. However, dam failures and flood issues has caused catastrophic damages and losses of lives and properties (Olukanni and Salami, 2008; Olukanni and Salami, 2012; Olukanni et al., 2016). To date, in Nigeria, more focus has been placed on construction of new structures, rather than maintaining existing ones. As a result, many of our civil infrastructures especially dams, are rapidly aging and deteriorating. Unless appropriately handled, ageing and deteriorating infrastructural systems can pose a significant problem, threatening economic prosperity and public safety. Thus, monitoring the state of a structure to ensure timely maintenance is critically important to preventing catastrophic disasters (Sim and Spencer, 2009).

Masonry dams are subject to deterioration processes, which are mainly related with aggressive environmental conditions, from either thermal and/or chemical origins. Generally, the chemical action of the water reservoir, when aggressive, associated to the annual thermal cycles of great amplitude, produce the chemical and physical degradation of the connective mortars of the masonry blocks of both the surfaces and core of the dam. The assessment of the serviceability and safety, as well as the selection of the maintenance and rehabilitation techniques, require an updated knowledge of the performance of the dams, based on monitoring and use of models. Therefore, the safety of these structures demands continual monitoring and in-depth analysis of the structural behavior, based on a large set of variables that contribute to the deformation. In fact, the deformation itself forms the most important parameter to be monitored.

The four case study dams; Unilorin, Malete, Okuta-Oja and Asa dams are located in Ilorin south, Moro, Ekiti and Ilorin West local government areas of Kwara State respectively.

2. Methodology

The research methodology includes:

- i. Reconnaissance survey: Measurements of parameters such as the crest length, dam height, estimated area and volume of case study dams. These were taken through direct measurements using measuring tapes, estimated area and dam volume from construction and design data.

- ii. Inspection round the dams to identify deteriorations in each dam station and conducting interviews for Dam Engineers at stations for additional information.

2.1 Results from Reconnaissance Survey

Shown in Table 1 are the measured dimensions of all case study dams while Table 2 shows specific information on the situations in the assessed dams. Figures 1-16 show the challenges of impact of neglect, ageing and relapsing in all the selected dams: Unilorin-, Maletе-, Okuta-Oja- and Asa-dam, respectively.

Table 1- Results from measurements of dam dimensions

Dimensions/Dam	Asa	Maletе	Okuta-Oja	Unilorin
Dam length l (m)	597	400	362	191
Crest width w (m)	5	6	1.5	5
Spillway length S_l (m)	65	30	50	50
Dam height H_d (m)	26	9.4	10.55	8.2
Storage capacity (Mm^3)	43	2.0	2.5	1.8

Table 2: Specific relapse information on the Assessed Dams

Dam	Unilorin dam	Okuta-Oja dam (Isapa)	Maleté dam	Asa dam (Ilorin)
Age	10 years	5 years	37 years	38 years
Deterioration	i. Seepage (2 piping outlets), Broken and eroded drain & retaining wall, ii. Broken and eroded drain & retaining wall, iii. Plant growth and coloration on spillway iv. Damaged and eroded baffle blocks v. reduced riprap boulders at dam toe vi. Plant and tree growth	i. Seepage from the concrete/rock interface ii. Seepage from the body of the concrete dam. iii. Seepage from the foundation of the dam. iv. Erosion of topsoil/earth at toe of dam from spillway water thus exposing foundation	Heavy seepage from an outlet	small trees and plant growth at embankment side
Deterioration Location	i. At left side downstream of dam. ii. Right side downstream wing wall iii. spillway of dam iv. stilling basin v. dam toe vi. Left and Right side upstream	i. right hand downstream of dam. ii right hand downstream of dam. right hand downstream of dam. iii. right hand downstream of dam iv. Dam toe	right hand downstream of dam	right hand upstream of dam
Possible Causes	i. piping outlet leading to seepage, ii. Weathering and erosion from drain water iii. large water algae loads, allowing growth of thick algae layer iv. force impact/erosion from spillway waters v. washing away by spillway run-off waters vi. Poor weed control	i. openings in between rock-concrete interface ii. Openings in between concrete -concrete interface due to different casting period. iii. openings in between rock-concrete interface/poor foundation preparation iii. inadequate or no riprap provision at toe	Uncontrolled piping outlet developed overtime into a heavy seepage source	Poor weeding practice

Figure 1 shows disorganized/reduced quantity of rocks/boulders for riprap at the toe of one of dams.



Figure1 Piping outlets leading to seepage



Figure 2 Broken and Eroded part of drainage at right-side retaining wall

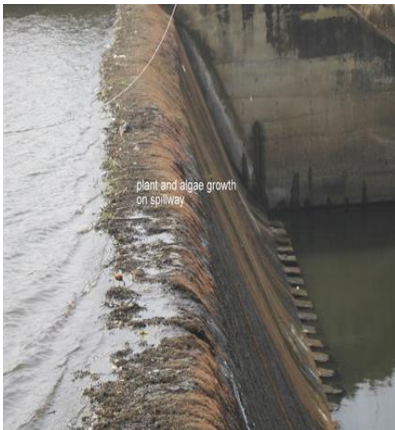


Figure 3. Plant/algae growth and blocks

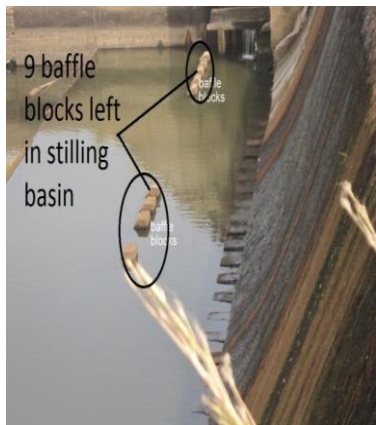


Figure 4 Damaged and eroded baffle decoloration of concrete spillway

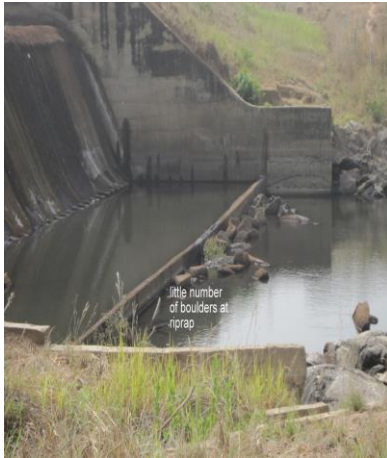


Figure 5 Washed-off riprap boulders at dam toe



Figure 6 Plants and small trees on upstream sides

Okuta Oja Dam



Figure 7 Seepage from the concrete/rock interface

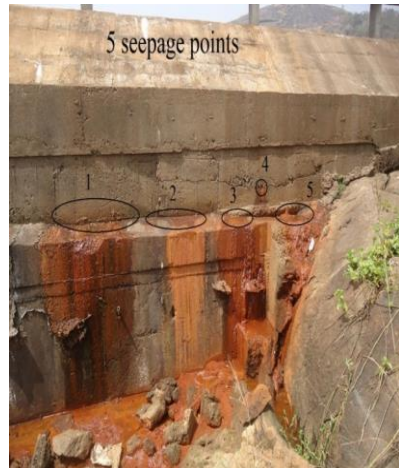


Figure 8 Concrete body seepage



Figure 9 Foundation seepage



Figure10 Scouring at dam toe

Malete dam



Figure 11 Re-construction in process



Figure12 Spillway under construction



Figure 13 Seepage from original dam

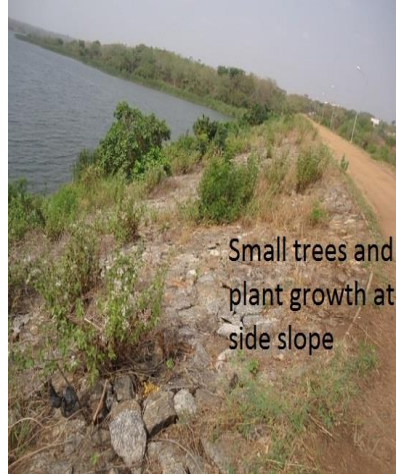


Figure 15. Small trees and plant growth on right side upstream of embankment

Asa dam



Figure 16 Spillway showing freeboard

Illustrated in Table 3 is a general summary of all surveys and measurements taken during the field work on case study dams.

Table 3-Summary of results from case study dams

Description	Asa dam	Malete dam	Okuta-Oja dam	Unilorin dam
1. Type of dam (Const. material)	Composite	Earth dam	Concrete	Earth dam
2. Dam owner	State govt.	Federal govt	Federal govt	Unilorin
3. Usage	Water supply	Water supply	Water supply & irrigation	Water supply
4. Estimated ³ capacity (Mm)	40	2.0	2.5	1.8
5. Age of dam (years)	37	36	4	9
6. Class of dam	Medium	Small	Small	Small
7. Dam dimension	597	400	362	191
Dam length, L (m);	5	6	1.5	5
Crest width, w (m);	65	30	50	50.0
Spillway length, S ₁ (m); Dam height H _d (m)	26	9.4	10.55	8.2
8. Vehicular traffic	No	No	No	No
9. Source of water contained in the dam	Asa river fed	Apodu river fed	River or rain run-off fed	Oyun river fed
10. Last date inspected	02/02/15	-----	-----	30/01/15
11. Has there been any form of repair/rehabilitation done on the dam in the past?	No	No	Yes but not successful (grouting).	No
12. Is the dam meeting up with the construction purpose?	Yes	No	Yes	Yes

3. Discussion of Results

3.1. Deteriorations observed and remedies for all dams

The commonest form of poor maintenance in dams can be observed as trees and plant growth at the side of embankments, most dam stations have been found guilty of this act (poor weed control). Small trees/tree crops are usually left to grow at embankment sides. The older the tree crop becomes, the stronger and bigger its roots becomes, the greater the penetration through the

compacted earth, which in turn creates seepage path for dam water to pass through. These plants should be uprooted regularly. Cultivation of Shallow rooted grasses will be advised as they will not only beautify the dam, but also help reduce washing away of earth from the side slopes through rain water.

Baffle blocks in dam stilling basin are installed to help cut/reduce the force impact of spillway water runoff such that the resulting force impact can be accommodated by the End Sill to allow gentle flow of water after spilling off the spillway towards the downstream. They help in energy dissipation which is to protect the downstream riverbed and banks from erosion and to ensure that the high velocity, turbulent flow from the outlet works does not undermine the dam and adjoining structures (FEMA, 2010). Once the baffle blocks are damaged or reduced in number (significantly, like that of the Unilorin earth dam), water spills from the spillway at a high velocity which will cause damage at downstream areas through erosion and washing away of banks and downstream areas. The distance between the chute blocks and baffle blocks, as well as the baffle blocks and end sill, is important for improved efficiency. Placing the baffle blocks too far upstream leaves them susceptible to cavitation and can cause waves downstream (FEMA, 2010). The design and construction of baffle blocks should also be supervised by a qualified Structural Engineer as weaving and knitting of the reinforcements should be done to design specifications. Damaged baffle blocks and areas in stilling basins should be repaired with shotcrete, a polymer improved cementitious mortar with aggregate that has a 28-day compressive strength over 48.3 MPa. It should be used to repair grout patches that had been damaged by erosion. Shotcrete is recommended for these repairs because it is fast setting, has exceptional bonding properties, and has an abrasion resistance six times greater than that of conventional concrete. This was used for similar repairs (baffle blocks and eroded spots) at the Old River Control Project located on the Mississippi River about 80 km (50 miles) northwest of Baton Rouge LA in 1988 (Curtis and McDonald, 1999).

Owing to the structural requirements of dams (elevation and slope), abrasion-erosion and cavitation damage of appurtenant structures and earth around flanges and retaining walls do occur. To minimize damage from cavitation, the designer should consider the cavitation index. This should however be attended to by construction and proper channeling of drainages, refilling and repairing of affected areas regularly. This can also be reduced by using high-strength concrete during construction and/or repairs. Ripraps at dam toe help

to reduce erosion of earth at the toe (Okuta-Oja and Unilorin dams). Checking of Riprap at toe of dam should be done seasonally so as to know the rate/extent of erosion of boulders and when to replace washed off quantity. Crack/seepage repair in Okuta-Oja dam; following the evaluation of the crack, a suitable repair procedure can be selected. The opening in the concrete in Okuta-Oja dam falls within the range of fine external crack $0.1062 < 0.2032$ mm ($0.004 < CW$ 0.008 inch).

3.1.1 Grouting of cracks and opening

Curtain grouting is performed to reduce deep underground seepage through the foundation and abutments. Pressure grouting using a mixture of cement and water or other materials is probably the most frequently used method to remedy serious foundation or abutment seepage problems in rock. However, it should not be used indiscriminately. Before any grouting effort, an investigation to determine the seepage conditions and locations should be conducted.

3.1.2 Injection of epoxy or Water tightening treatment

Repair of large cavities in concrete & masonry dams by Hybrid Polyurethane Injection Resin like TamPur 115,116 which is an example of a non-Foaming PU Resin which is used for cavity filling in concrete in both under water and above water. It's a silicate modified PU resin and two component system. TamPur 115 & 116 can be used for any big cavity filling in Masonry or Concrete dam in underwater by using a twin piston PU pump from top. However, trained diver is needed for such repair under supervision from an experienced Engineer who has knowledge of such materials and its application (Mukhopadhyay, 2014).

Other forms or rehabilitations may include;

- (i) excavation and replacement of earth;
- (ii) in-situ densification;
- (iii) in-situ strengthening;
- (iv) increasing the freeboard; and
- (v) drainage repairs

4. Conclusions and Recommendation

It can be concluded that there is poor maintenance culture of dams in the state as two of four case study displayed key deteriorations that usually develops

into failure, and one has failed and is undergoing reconstruction. From this research, repairs or renovations of these structural dams involve more extensive and intrusive work, which if performed improperly could endanger the structure, and therefore must be performed under the supervision of a professional engineer, in accordance with their initial designs approach. Yearly deterioration assessment should be carried out on the dams after every rainy season and reports taken should be submitted to appropriate quarters for timely considerations.

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