DETERMINATION OF MOST ECONOMIC HEIGHT OF A DAM

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Abstract
Dam projects are very costly projects all over the world. Also, in case of dam failure, the effect is always catastrophic and devastating. This leads to loss of human lives and devastating environmental effects. In view of these, it is required that dam projects be well designed to prevent above adverse effects and to optimize the total cost. Dam height is a very important variable/feature that determines the stability and functionality of the facility. This work aims at discussing how to provide a dam height that will be cost effective, sustainable and provide a facility that will be functional for optimum benefits.

Keywords: Dam Failure, Sustainable, Stability, Optimum Benefits.

1. Introduction

The usefulness of water cannot be over-emphasized. Water, being a natural resource is indispensible and is required by all living things for sustenance of life. It is available in streams, rivers, lakes and in underground water. The availability varies depending on the season of the year and the source. It is practically impossible to make a healthy living without good quality water. It is required for different functions including drinking, hydro power generation, irrigated agriculture, navigation, flood control, recreation, sanitation, wild life development and groundwater recharge.

The problem is that it is difficult to have water in adequate quantities for above functions due to seasonal changes and other factors.

Dams serve as centres of tourist attraction, creating jobs for the unemployed, a rich source of fish and a fallback in times of drought, a dam also creates electricity from nothing other than the falling of water through its turbines. In Nigeria, like in many other parts of the world, dam projects are often seen as key to economic solution through hydroelectric power generation and supply.

Incorrect calculation of flood flows, dam heights and other factors have led to many dam failures. Moreover, lack of proper feasibility studies, construction inadequacies and poor dam reservoir operation and maintenance have led to drastic reduction of the life span of dams due to enhanced reservoir sedimentation.

Dams potentially provide social and economic benefits but at the same time pose a threat to lives and livelihoods and the environment [1]. Dam owners have a legal obligation, in most jurisdictions, to ensure that dams are operated in a way that optimizes economic and social outputs while not compromising safety.

Considering that world population has exceeded 6 billion in 2002 (growing annually by 70-80 million), and that 20% suffer from chronic water shortage, and that 2.6billion people have no access to any sanitary facilities, one can only conclude that there is unmistakably an upcoming crises for an adequate water supply, food supply and health care. Everyday, 6000 people die because of lack of water [2], [3]. According to the latest UN goals, 0.6 billion people should be relieved from this situation by 2015. In addition by 2030, two thirds of all people will live in cities, and mankind will need 55% more food.

This crisis can only be met by an economy using larger water quantities with improved quality through the construction of more dams. At the same time, in coastal areas, a substantial use of sea water will probably be necessary to meet the increasing needs of mankind [3].

2. Dam Problems

Dams present some negative effects on the environment. These problems are handled since a long time ago by multiple professional bodies, such as the International Commission on Large Dams (ICOLD) founded in 1928, supported by 82 member countries, and the World Commission on Dams, initiated in 1997 by the World Bank. Another problem of dams is the disturbances to fauna and flora through the storage and hence removal of natural flow conditions downstream can be mitigated through an adequate and dynamic water management.

Another problem of dams is the deposition of till and fine-grained soil materials, i.e. sedimentation and silting at the expenses of the reservoir. About 1% of volume of the reservoir is lost to sedimentation annually [4].

3. Most Economic Height of a Dam

Cost is a very important variable in engineering projects and all projects in general. Engineers in particular aim at optimizing cost in all they do. In dam projects, it is very important that cost is analyzed so that money is not expended more than necessary. For a given length of dam, cost increases with height. So, it is required that this cost be evaluated to give minimum value.

The economic height of a dam is that height of the dam, corresponding to which the cost of the dam per unit of storage is minimum [5].
This height of dam is determined by preparing approximate estimates of cost for several heights of dam at a given site [6]. See figure 1. To achieve this, the estimates are prepared for construction costs, for several heights of the dam, somewhat above and below the level at which the elevation-storage curve shows a fairly high rate of increase of storage per unit rise of elevation, keeping the length of the dam moderate (Fig 1). The construction cost is found to increase with the dam height (Fig 2).

Considering each dam height, the reservoir storage is known from the reservoir-capacity curve. The construction cost per unit of storage for all the possible dam heights is now calculated and plotted.

The height that corresponds to the lowest point on the curve, gives the dam height for which the cost per unit of storage is minimum, hence, the most economical (Fig 3).

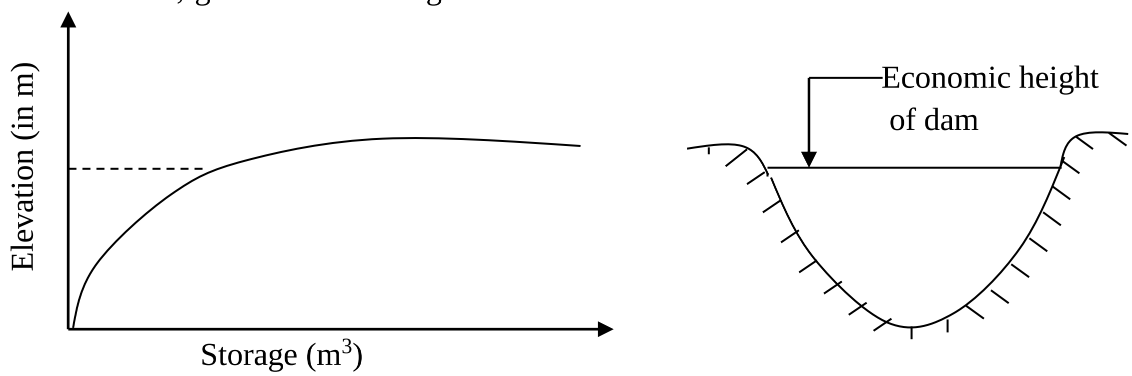

Fig 1. Cross Section at dam site

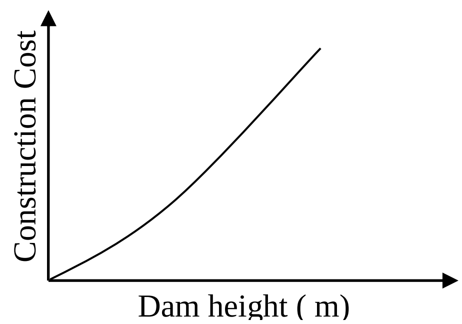

Fig 2. Plot of construction cost versus dam height

Cost per unit storage capacity, q is presented.

where,

$H_1, H_2, H_3 \ldots H_n$ are different heights of dam at the dam site

$C_1, C_2, C_3 \ldots C_n$ are corresponding costs per capacity for different heights of dam

$$q_1 = \frac{C_1}{Q_1}$$

$$q_2 = \frac{C_2}{Q_2}$$

$$q_n = \frac{C_n}{Q_n}$$

The structural height of a dam is the total distance between the lowest point of the foundation surface to the top of the dam. (The top of the dam excludes kerbs, parapet walls, camber for settlement, guard rails etc).

Table 1. Minimum free board allowance (m) for different heights of dam.

Height of dam (m)	Minimum freeboard allowance (m)
Less than 50	1
50-100	2
Greater than 100	25

Source: [6]

Table 2: Cost per capacity for different dam height in a dam site.

Height (m)	Storage Capacity (m^3)	Cost (₦)	Unit Cost (Cost/Cap) ₦/m^3
H_1	Q_1	C_1	q_1
H_2	Q_2	C_2	q_2
H_3	Q_3	C_3	q_3
H_4	Q_4	C_4	q_4
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H_n	Q_n	C_n	q_n

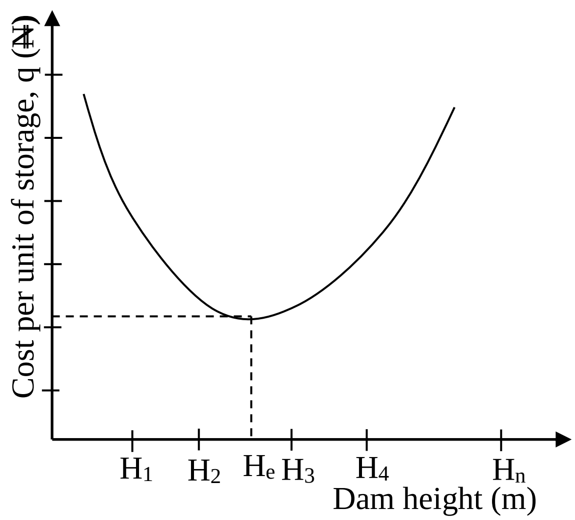

Fig 3. Graph of cost per unit of storage versus dam height.

Economic dam height occurs at a location which corresponds to H_e.

Economic height of a dam is the height at which:

(a) Cost of dam/storage = min capacity

(b) Benefit/cost > 1.0.

4. Conclusion

It is required for any dam site that all considerations during the feasibility studies should be taken care of adequately. There, if adequately adhered to, will ensure a sustainable, comprehensive and cost effective dam if constructed. One of these considerations, the dam height, must be adequately analyzed and provided as discussed to ensure a safe and sustainable dam facility.

If inadequate height is provided, it may lead to overtopping. Also, if height is provided in excess of what is required for optimal performance and benefits, then the cost will be very high making it to be cost in-effective. This paper focused on methodology of arriving at most economical dam height.

In addition to above height, to ensure that the dam is not overtopped, provision must be made above normal reservoir level (i.e. free board) for the effects of ponding during the passage of the design flood, sieche effects in the reservoir, wind set up of the water in the reservoir, waves induced by wind and waves induced by earthquakes or their after effects such as landslides.

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