Study on the Dam & Reservoir, and Analysis of Dam Failures: A Data Base Approach

Mohit Kumar Bharti[1], Manish Sharma[2], Dr. Nazrul Islam[3]

[1]*Student, Department of Civil Engineering, Rajkiya Engineering College, Bijnor (U.P.), India*
[2]*Assistant Professor, Department of Civil Engineering, Rajkiya Engineering College, Bijnor (U.P.), India*
[3]*Professor, Department of Civil Engineering, Jamia Millia Islamia, New Delhi, India*

***

Abstract – *Engineering geologists provide the basic geological and geotechnical recommendations based on certain details analysis and design associated survey. These structures include dam as the major construction project. Explains different aspects related to dams, types of dam and cause of failure. Natural disaster like earthquake, flood, rockslides, and poor design or lack of maintenance affect the dam structure. Failure of dams occur because of overtopping, inadequate spillway capacity, excessive seepage across the body, alkali aggregate reaction, cavitation in energy dissipaters, stresses due to external force, gates of dam not working effectively etc. Excessive scouring below spillway may be dangerous for foundation. Analysis and study of failed dam structure can give reasons behind the failure of any dam.*

Key Words: Reservoir, Dams, Dam breach, Overtopping, seepage, piping

1. INTRODUCTION

water resource engineering is concerned with the utilization of water, control of water, and water quality management. Water is utilized for various beneficial purpose of irrigation, water supply, hydropower and navigation. Water controlled and regulated for a variety of purpose such as flood control, land drainage sewerage and bridges so that it does not cause damage to property, inconvenience to the public, or loss of life. Water quality management of pollution control is also an important phase of water resource engineering to maintaining the required quality of water for municipal and irrigation uses and preserve the environment and ecological balance.

1.1 Various purpose

(A) Main purpose: The following are the main purpose
1. Irrigation
2. Hydroelectric power
3. Flood control
4. Domestic and industrial water supply
5. Navigation

(B) Secondary purpose: The following secondary purposes are also served by various projects
1. Recreational
2. Fish and Wildlife
3. Drainage control
4. Watershed management
5. Sediment control
6. salinity control
7. Pollution abatement
8. Insect control
9. Artificial precipitation

(C) Miscellaneous purpose: In addition to above main and secondary purposes, water resources development serves the following miscellaneous purposes:
1. Employment
2. Acceleration of public works

2. RESERVOIR

A reservoir is a large, artificial lake created by constructing a dam across the river. Broadly speaking, any water pool or lake may be termed a reservoir. However, the term reservoir in water resources engineer is used in a restricted sense for a comparatively large body of water stored on the upstream of a dam constructed for this purpose. Thus, a dam and a reservoir exist together. This is especially for a country like India in which about 75% of the total precipitation occurs during the monsoon season from June to September. Most of the river carry very little or no water during non-monsoon period, except the Himalaya rivers, which also carry substantial discharge in the non-monsoon period due to melting of snow. During the period of low flow, it is not possible to meet the water demand for various purpose such as irrigation, water supply and hydroelectric power. To regulate the water supplies, a reservoir is created on the river to store water during rainy season. The store water is later released during the period of low flows to meet the demand. In the monsoon season, the reservoir store excess water when the discharged in the river is high. Thus, besides releasing the water during the period of flows, the reservoir also helps in flood control.

2.1 Types of reservoirs

If reservoir serves only one purpose, it is called a *Single Purpose reservoir.*

On the other hand, if it is serving the more than one purpose, it is termed as *Multi purposes reservoir.*

Because in most of the cases single purpose reservoir is not economically feasible, it is the general practice in India to develop multipurpose reservoir.

Depending upon the purpose served, the reservoir may be broadly classified into 5 types:

1. Storage reservoir[conservation reservoir]
2. Flood control reservoir
    i. Detention reservoir
    ii. Retarding reservoir
3. Multipurpose reservoir
4. Distribution reservoir
5. Balancing reservoir

2.2 Storage capacity of reservoir

The storage capacity of a reservoir is therefore, its most important characteristics the available storage capacity of a reservoir depends upon the topography of the site and the height of dam. To determine the available storage capacity of a reservoir upto a certain level of water, engineering survey are usually conducted for preliminary estimates of the capacity, the survey of India maps can be used.

1. Trapezoidal formula: According to the trapezoidal formula, the storage volume between two successive contours of areas A_2 and A_2 is given by

$$\Delta V=\frac{h}{2}(A_1+A_2)$$

Where, h is the contour interval. Therefore, the total storage volume is V

$$V=\frac{h}{2}(A_1+2A_2+2A_3+2A_4+A_{n-1}+A_n)$$

Where. n is the total number of areas.

2. Cone formula: According to the cone formula, the storage volume between two successive contours of areas A1 and A2 is given by

$$\Delta V=\frac{h}{3}[A_1+A_2+\sqrt{(A_1A_2)}]$$

3. Prismoidal formula: According to the prismoidal formula, the storage volume between three successive contours is given by

$$\Delta V=\frac{h}{6}(A_1+4A_2+A_3)$$

The total storage volume is

$$V=\frac{h}{3}[(A_1+A_n)+4(A_2+A_4+A_6+....+A_{n-2})+2(A_3+A_5+A_7+......+A_{n-2})]$$

4. Storage Volume from cross-sectional areas: In the absence of adequate contour maps, the storage volume can be computed from the cross-sectional areas of the river. Cross sectional areas (a_1, a_2 ... etc) are obtained from the cross-sections of the river taken upstream of the dam up to the u/s end of the reservoir at regular interval d. The volume is determined from the prismoidal formula. The formula is applicable for odd number of sections

$$V=\frac{h}{3}[(a_1+a_n)+4(a_2+a_4+a_6+....+a_{n-2})+2(a_3+a_5+a_7+......+a_{n-2})]$$

2.3 Basic terms and definitions

A large number of terms are commonly used for reservoir planning. These terms are:-

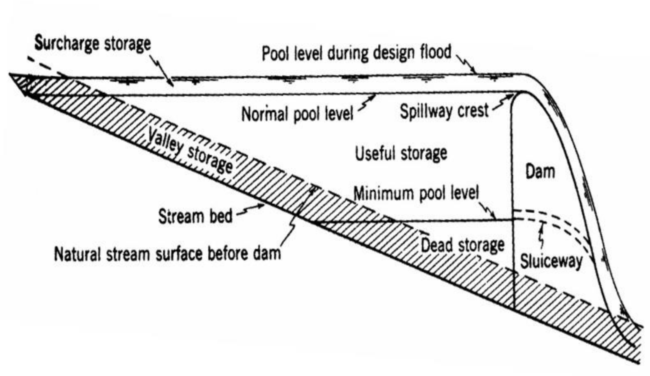

Fig. 1 Basic terms of reservoir

3. DAM

A dam is a barrier or large impounding structure designed and constructed on a water course to confine large volume of water and then control the flow of water. A dam and a reservoir are complements to each other.

A distinction between weir and dam. A weir is also a structure built across a river; however, its purpose is not to store water but to divert it. Dams are generally constructed in the mountainous reach of the river where the valley is narrow and the foundation is good. Generally, a hydropower station is also constructed at near the dam site to develop hydropower. The river to divert and the water released from the dam into canals for irrigation and other purpose.

3.1 Historical development of dam in India

In India the weirs and barrages, from the ancient times, had been constructed on the small streams at local level for irrigation and drinking purposes. Had only village level irrigation, there were also big dams, anicuts, large reservoirs and canals built by ancient Indian kings as well as tanks and check dams at a village level. However, during the colonial period, the little attention has been paid because the British knew very little about irrigation as compared to the Indian [cotton, 1874]. However, in the first half of 19th century, they started paying attention to develop the irrigation system. The agriculture was the sole mainstay which was mainly depended on the rainfall or irrigation. The British colonizer was to generate revenue and to control over the cropping patterns in India, so that the efforts had been directed to construct a permanent dam structure to reign over hydro-electricity. The construction of dams and reservoirs when the level of industrialization has increased in India after the recovery of First World War. It was also considered that the dams are the necessity of any modern irrigation and irrigation through large dams is synonymous of good irrigation with maximum Government benefits. The Krishnaraja sagar hydro-electric plant was completed in 1931.

3.2 Basic Terminology of Dams

1. Abutment: The part of a valley side (wall) against which a dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment.
2. Gallery: A passageway within the body of a dam or abutment, hence the terms "grouting gallery", "inspection gallery", and "drainage gallery".
3. Spillway: A structure over or through which flood flows are discharged.
• Controlled Spillway - If the flow is controlled by gates, it is called a controlled spillway
• Uncontrolled Spillway - If the elevation of the spillway crest is the only control, it is called an uncontrolled spillway

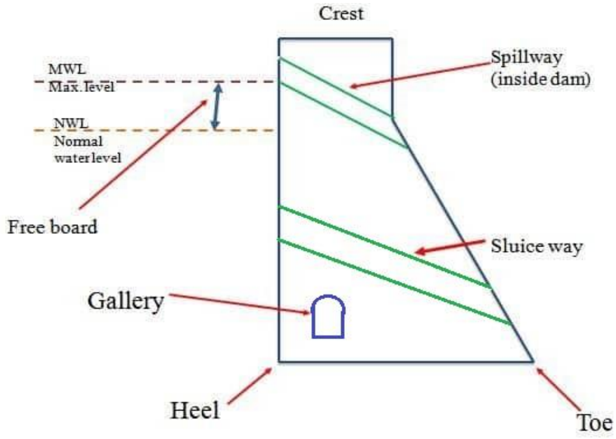

Fig. 2 Components of Dam.

4. Crest: The top of the Dam. These may in some cases be used for providing a roadway or walkway over the dam. Parapet walls: Low Protective walls on either side of the roadway or walkway on the crest.

5. Heel: Portion of Dam in contact with ground or river-bed at upstream side.

6. Toe: Portion of dam in contact with ground or river-bed at downstream side.

7. Sluice way: Opening in the dam near the base, provided to clear the silt accumulation in the reservoir.

8. Free board: The space between the highest level of water in the reservoir and the top of the dam.

9. Dead Storage level: Level of permanent storage below which the water will not be withdrawn.

3.3 Classification of dams

[a] Based on size:
1. Large (big) dam
2. Small dam
International commission on large dams(ICOLD), assumes a dam is big when its height is bigger than 15meter. If height of the dam is between 10meter to 15meter and matches the following criteria, then ICOLD accepts the dam is big:

- If the crest length is bigger than 500meter
- If the reservoir capacity is larger than 1 million m^3
- If the flood discharge is more than $2000m^3/s$
- If there are some difficulties in the construction of foundation.

[b] Based on height:
i. High dam or large dam – Height is bigger than 100m.
ii. Medium dam – Height between 50m to 100m.
iii. Low dam or Short dam – Height less than 50m.
[c] Based on Function Served:

1. Storage dams
2. Detention dams
3. Diversion dams
4. Debris dams
5. Coffer dams

[d] Based on Hydraulic design:
1. Overflows dams
2. Non-overflow dams

[e] Based on Material of Construction:
1. Masonry dam
2. Concrete dam
3. Earth dam
4. Rockfill dam
5. Timber dam
6. Steel dam
7. Composite dam

[f] Based on Rigidity:
1. Rigid dams
2. Non-rigid dams

[g] Based on the Structural design:
1. Gravity dam
2. Earth dam
3. Rockfill dam
4. Arch dam
5. Buttress dam

3.4 Data about dams

Total large dams in the world – 57000 (by ICOLD)

Table 1. Top 10 countries they have large no. of dams

S.N.	Country	Number
1.	China	23000
2.	United State of America	9263
3.	India	5202
4.	Japan	3130
5.	Brazil	1365
6.	Korea	1338
7.	Canada	1150
8.	South Africa	1116
9.	Spain	1064
10.	Turkey	973

Total dams in India – 5202

Table 2. Top 10 Highest Dams in India

S.N.	Dam	Height(m)	Purpose	River	Located
1.	Tehri Dam	260.5	I, HP, W	Bhagirathi	Uttrakhand
2.	Bhakra Nangal Dam (Govind Sagar reservoir)	226	I	Sutlej	Himachal Pradesh
3.	Idukki Dam	168.91	HP	Periyal	Kerala
4.	Koldam Dam	167	HP	Sutlej	Himachal Pradesh
5.	Sardar Sarovar Dam	163	I, HP	Narmada	Gujarat
6.	Ranjit Sagar Dam	160	I, HP	Ravi	Jammu & Kashmir
7.	Srisailam Dam	145.1	HP	Krishna	Andhra Pradesh
8.	Chamera Dam	140	HP	Ravi	Himachal Pradesh
9.	Nagarjuna Sagar Dam	124	I, HP	Krishna	Andhra Pradesh
10.	Koyna Dam	103	HP	Koyna	Maharashtra

Where,

I = Irrigation
HP = Hydropower
W = Water supply

3.5 Procedure to build a dam

Step I: Dewatering the part of river valley at selected site of dam which is achieved by diverting the river through a tunnel.
1. Provision of diversion tunnel is made.
2. Construction of dam in two stages.
3. Construction of galleries in gravity dams.

Step II: Work is started at river during summer i.e. when river flow is low. Earth-moving equipment is used to build coffer dam on upstream of main construction area.
1. Pumping is regularly done to remove water that may seeps through the coffer dam.
2. Diversion tunnels are not required in case of concrete gravity dams and only if water is channelled through a water pipe is satisfactorily.

Step III: Removal of loose rock and rubble from the valley wells and river bed.
1. Concrete faced rock fill dams required a footing to be constructed around their upstream edge.
2. The plinth is made from concrete and serves as a foundation or connection between the dams and valley walls & floor.
3. The area under plinth is water proofed by drilling holes and pumping cement grout into cracks in the rock.

Step IV: During dam construction, the associated power station and intake works also being built if hydropower generation is to be generated.

Step V: Once dam is completed; diversion tunnel is closed and lake beings to fill.

3.6 Force acting on gravity dam

1. Water pressure, 2. Uplift pressure, 3. Silt pressure, 4. Wave pressure, 5. Earthquake force, 6. Ice pressure, 7. Wind pressure, 8. Self-weight of dam.

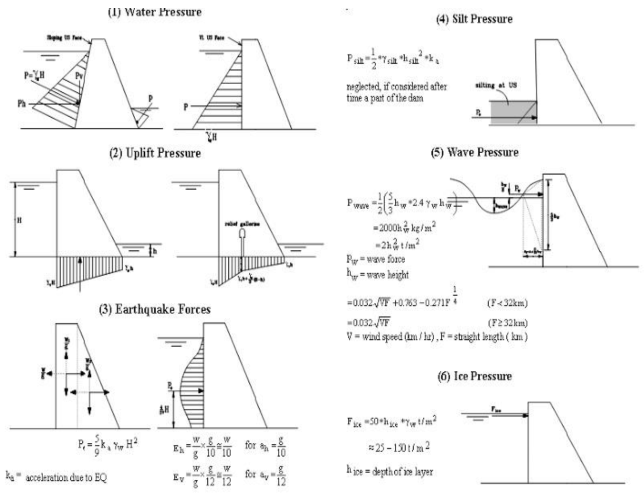

Fig. 3 Force acting on dam

4. FAILURE OF DAM

While dams provide the ability to control the flow of fresh water and function to simplify our lives in many ways, they also pose an inherent and inevitable threat to the environment and to public safety. Dams has been failing due to unpredictable environmental conditions, poor engineering, or improper management.

Historically the vast majority of dam failures have been caused by overtopping and piping. Dam overtopping can also cause a pulse downstream of a dam without the dam failing due to the stage discharge relationship of the reservoir. Dam overtopping and dam failure are very difficult process to understand, predict, analyze, or model due to the inherently complex and contextual nature of the overtopping and failure processes and the lack of existing data relevant to dam failure.

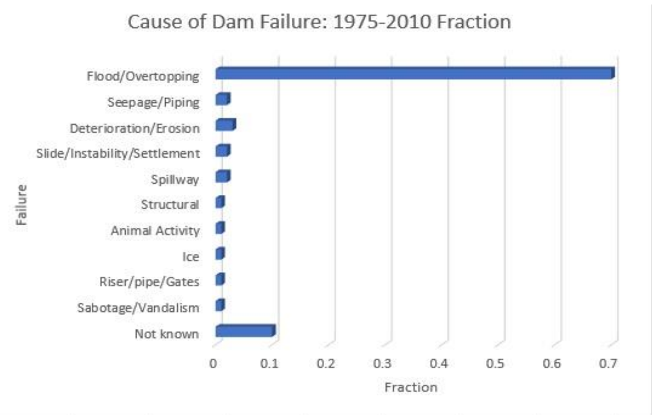

Fig. 4 Cause of dam failures

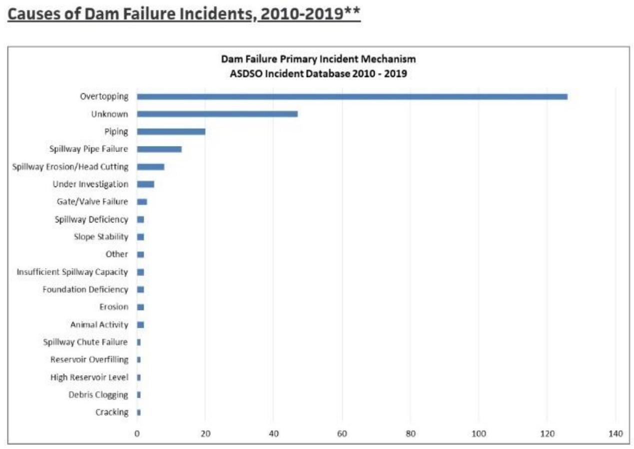

Fig. 5 Dam failure primary incident

4.1 Common cause of dam failure

Overtopping: It is caused due to heavy rain and water flow over the dam structure. This is the major failure in dam created by heavy flood.

Foundation defect: This failure occurs as a result of settling in the foundation of the dam, uplift pressure, and seepage around the foundation.

Piping and Seepage: This failure occur as a result of internal erosion caused by seepage and erosion along hydraulic structures such as the spillways. As well, erosion as a result of animal burrows and cracks in the dam structure contribute to this failure.

Conduit and Valve failure: These failures occur as a result of problems with values and conduits.

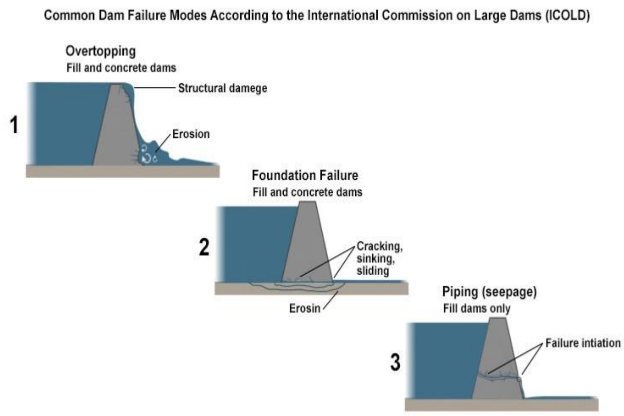

Fig. 6 Common dam failure modes

4.2 Many other causes of dam failure are mentioned below:

1. Water Breaching

2. The foundation of the dam is inadequate

3. Piping cause erosion of the foundation

4. Subsidence and the movement of the foundation

5. Variation in temperature unequally throughout the dam structure

6. Uplift from the ground and sliding of the structure

7. Dynamic blasting in the nearby areas causing vibration to the dam structure.

8. Seismic load action

9. Wave action on the structure and weak energy absorption characteristics of the structure

10. Higher amount of silting causing greater loads that expected during the design of the dam

11. The concrete and nearby rock or the soil surface loosing shear capacity.

4.3 Four hidden cause of dam failure

1. Change in land use

Says Norbert Delatte
Professor of civil engineering at Cleveland State University

2. Change in Weather pattern

Says France

3. Outdated designs

4. Lack of Maintenance and Funding.

4.4 Data of dam failure

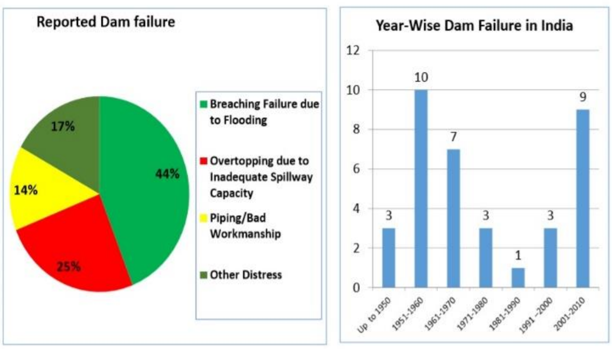

Fig. 7 Dam failure in India by DRIP

Table 3. Out of 36, 30 in respect in earth dams

Types of dam	Nos. of failure	%failure
Earth dams	30	83.33%
Composite dams	3	8.33%
Masonry dams	3	8.33%
Total	36	

Table 4. List of major dam failure

Dams	Date	Country	Fatalities	Details
Puentes dam	1802	Spain	608	1800 house and 40000 trees destroyed.
Iruka lake dam	13/5/1868	Japan	941	Overtopping
Mill river dam	1874	U.S.	139	Piping
South fork dam	31/5/1889	U.S.	2208	Poor Workmanship, heavy rainfall
Walnut Grove dam	1890	U.S.	100	Heavy snow and rain
Gohna Lake dam	25/8/1894	British India	1	Landslide
Austin dam	7/4/1900	U.S.	8	Landslide
Hauser dam	14/4/1908	U.S.	0	Heavy flooding with poor foundation quality
Broken down dam	24/9/1908	U.S.	0	Dam built on water springs
Austin dam	11/9/1911	U.S.	78	Poor design, use of dynamite to remedy structural problems
Desna dam	1916	Austria-Hungary	62	Construction flaws caused the dam failure.
Lower Otay dam	1916	U.S.	14	Overtopping
Sweetwater dam	27/1/1916	U.S.	0	Overtopping
Lake Toxaway dam	13/8/1916	U.S.	0	Overtopped
Tigra dam	19/8/1917	British India	1000	Failed due to water infiltrating through sandstone foundation
Gleno dam	1/12/1923	Italy	356	Poor construction of design
Llyn Eigiau dam	2/11/1925	U.K.	17	Outflow
St. Francis dam	12/3/1928	U.S.	451+	Geological Instability
Castlewood dam	3/8/1933	U.S.	2	Bad design and maintenance
Granadillas dam	1934	Spain	8	Bad design and foundation
Secondary dam of Sella Zerbino	1935	Italy	111	Geological unstable base combined with flood
Horonai dam	1941	Japan	60	Overtopping
Nant-y-Gro dam	1942	U.K.	0	World War II
Eder see dam	17/5/1943	Germany	70	World War II
Mohne dam	17/5/1943	Germany	1579	World War II
Xuriguera dam	1944	Spain	8	Heavy rain
Heiwa lake dam	1951	Japan	117	Heavy rain
Taisho lake dam	1951	Japan	108	Heavy rain
Vega de tera	9/1/1959	Spain	144	Poor construction

Malpas set dam	2/12/1959	France	423	Geological fault
Kurenivka mudslide	13/3/1961	Ukrainian	1500	Heavy rain
Planchet dam	12/7/1961	India	1000	Dam wall burst due to rain water
Vajont dam	9/10/1963	Italy	2000	Wave over the top of dam, landslide into lake
Spaulding pond dam	6/3/1963	U.S.	6	Unknown
Swift dam	10/6/1964	U.S.	28	Heavy rain
Mina plakalnitsa	1/5/1966	Bulgaria	107	Unknown
Sempor dam	29/11/1967	Indonesia	138	Over-topped
Gurtej dam	30/10/1971	Romania	89	Too tall collapsed
Canyon lake dam	9/6/1972	U.S.	238	Flooding, dam outlets clogged
Shimantan dams	8/8/1975	China	171000	Extreme rainfall
Teton dams	5/6/1976	U.S.	11	Seismic activity
Laurel run dam	19/7/1977	U.S.	40	Heavy rainfall
Kelly Barnes dam	6/11/1977	U.S.	39	Unknown
Machchu dam	11/8/1979	India	5000	Heavy rain
Wadi Qattara dam	1979	Libya	0	Storage capacity damaged, Overtopping
Lawn lake dam	15/7/1982	U.S.	3	Piping
Tous dam	20/10/1982	Spain	8	Overtopping
Val di Stava dam	19/7/1985	Italy	268	Poor Maintenance
Kant ale dam	20/4/1986	Sri Lanka	180	Piping, poor Maintenance
Upriver dam	20/5/1986	U.S.	0	Overtopping
Belci dam	29/7/1991	Romania	25	Overtopping
Peruca dam	28/1/1993	Croatia	0	Explosives
Merrie spruit tailings dam	22/2/1994	South Africa	17	Heavy thunderstorm
Meadow pond dam	13/3/1996	U.S.	1	Heavy icing conditions
Opuha dam	6/2/1997	New Zealand	0	Heavy rain during construction
Virgen dam	1998	Nicaragua	?	Heavy rain, Overtopping
Shihgang dam	21/9/1999	Taiwan	0	Earthquake
Zeyzoun dam	4/6/2002	Syria	22	Individuals displacement
Silver lake dam	14/5/2003	U.S.	0	Earth dam heavy rain
Hope mills dam	26/5/2003	U.S.	0	Heavy rain, overtopping
Big bay dam	12/3/2004	U.S.	0	Piping
Camara dam	17/6/2004	Brazil	3	Poor Maintenance
Shakidor dam	10/2/2005	Pakistan	70	Sudden and extreme flooding
Taum Sauk reservoir	14/12/2005	U.S.	0	Piping
Ka loko dam	14/3/2006	U.S.	7	Heavy rain flooding
Campos Novos dam	20/6/2006	Brazil	0	Tunnel collapse
Gusau dam	30/9/2006	Nigeria	40	Heavy flooding, Lack of Maintenance
Koshi barrage	18/8/2008	Nepal	250	Multi-year drought preceding
Algo does dam	27/5/2009	Brazil	7	Heavy rain
Situ gintung dam	27/3/2009	Indonesia	98	Poor Maintenance and heavy monsoon rain
Sayano-shushenskaya dam	17/8/2009	Russia	75	Overtopping
Kyzyl-Agash dam	11/3/2010	Kazakhstan	43	Heavy rain and snowmelt
Hope mills dam	16/6/2010	U.S.	0	Piping
Testa Linda dam	13/7/2010	Canada	0	Heavy rain low maintenance
Delhi dam	24/7/2010	U.S.	0	Heavy rain flooding
Niedow dam	7/8/2010	Poland	1	Overtopping
Fujinuma dam	11/3/2011	Japan	8	Heavy snowmelt
Campos dos goytacazes dam	4/1/2012	Brazil	0	Failed after a period of flooding
Ivanovo dam	6/2/2012	Bulgaria	8	Heavy snowmelt
Kopru dam	24/2/2012	Turkey	10	Heavy rain
Dakrong 3 dam	7/10/2012	Vietnam	0	Poor design
Tokwe mukorsi dam	4/2/2014	Zimbabwe	0	Downstream slope failure
Mount polley tailings dam	4/8/2014	Canada	0	Overfilled beyond design
Manana dam	5/11/2015	Brazil	19	Tailing dam collapse
Patel dam	10/5/2018	Kenya	47	Unclear, heavy rain
Panjshir valley dam	11/7/2018	Afghanistan	10	Heavy summer rain
Xe-pian Xe-namnoy dam	23/7/2018	Laos	36	Saddle dam under construction
Swar Chaung dam	19/8/2018	Myanmar	4	Breach in dam spillway
Sanford dam	15/9/2018	U.S.	0	Overtopping
Brumadinho dam	25/1/2019	Brazil	217	Tailings failure
Spencer dam	14/3/2019	U.S.	?	Unknown
Tiware dam	2/7/2019	India	23	Heavy rain overtopped and breaches the dam

4.5 Solution for precaution against failure

1. Cut-off wall should be provided for every type of dam structures. It will prevent the inundation of the flood below the dam.

2. The cut-off wall will prevent the quick sand condition.

3. Seepage of the dam reduce by the new design structure of dam.

4. Does not lack of the maintenance of dam.

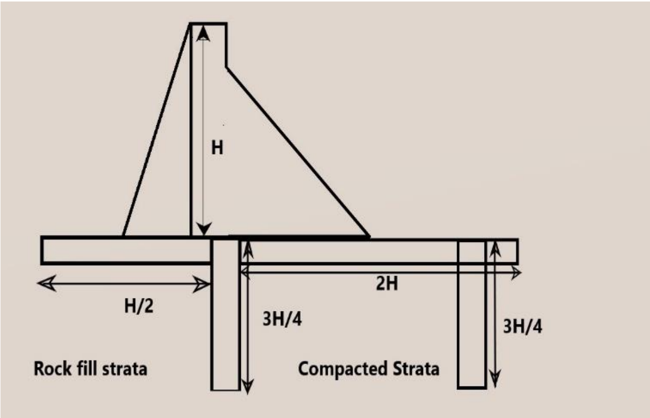

Fig. 8. Gravity dam Structure

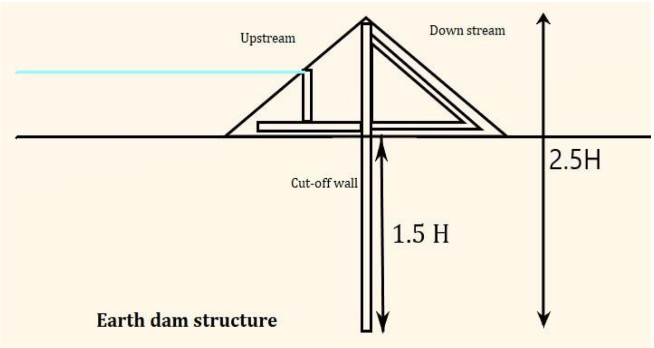

Fig. 9. Earth dam Structure

5. To prevent overturning, the resultant of all forces acting on the dam should remain within the middle-third of the base width of the dam.

6. In the dam, the sliding should be fully resisted when the condition for no sliding exists in the dam section.

7. In the dam section, the compressive stresses of concrete or masonry should not exceed the permissible working stress to avoid failure due to crushing.

8. There should be no tension in the dam section to avoid the formation of cracks.

9. the factor of safety should be maintained between 4 to 5.

10. This earth dam structure will neglect the seepage or piping failure(fig.9).

5. Conclusion

In ancient times, dams were built for the single purpose of water supply or irrigation. As civilization developed, there was a greater need for water supply, irrigation, flood control, navigation, water quality, sediment control and energy. Therefore, dams are constructed for a specific purpose such as water supply, flood control, irrigation, navigation, sedimentation control, and hydro-electricity. The demand for water is steadily increasing throughout the world. There is no life on the earth without water, our most important resources apart from air and land.

Highlighted the different general aspects of dams, their types and the cause of failure. And giving the data previous failed the dam in the world. Mostly earth dams are failed by seepage/piping.

REFERENCES

[1] S. K. Garg, “Irrigation Engineering and Hydraulic Structures,” 16th Edition, Khanna Publishers, Delhi, 2002, pp. 960-1020.

[2] Dr. B.C. Punamia, “Irrigation and Water Power Engineering”, 15th Edition, Laxmi Publications.

[3] Design Manual for Concrete Gravity Dams – United States Bureau of Reclamation

[4] Gravity Dam Design – US Army Corps of Engineers

[5] Criteria for Design of Solid Gravity Dams – Bureau of Indian Standards (IS 6512 - 1984)

[6] Module 4: Hydraulic structures for flow diversion & storage, Version 2 CE IIT Kharagpur

[7] Module: Evaluation of concrete dam stability by TADS (Training Aids for Dam Safety)

[8] Safety guidelines for design of gravity dam by Federal energy regulatory commission (FERC)

[9] Design & construction of concrete gravity dam by National Programmed on Technology Enhanced Learning (NPTEL)

[10] Analysis of gravity dam by theconstructor.org.in (https://theconstructor.org/structures/analysis-of-gravity-dam/5204)

[11] Stability analysis of concrete gravity dam by scientific.net (https://www.scientific.net/AMM.238.252)

[12] Design & analysis of concrete gravity dam by research gate

(https://www.researchgate.net/.../281320646)

[13] “Comparison of Design and Analysis of Concrete Gravity Dam” - Md. Hazrat Ali, Md. Rabiul Alam, Md. Naimul Haque, Muhammad Jahangir Alam (Department of Civil Engineering, Chittagong University of Engineering & Technology, Chittagong, Bangladesh)

[14] The Cemented Material Dam: A New, Environmentally Friendly Type of Dam - China Institute of Water Resources and Hydropower Research, Beijing

[15] Study on Cemented-Rockfill Dam College of Civil and Hydropower Engineering, China Three Gorges University, Yichang, China.

[16] Modern Structural and Technological Solution for New Large Dams www.hydroworld.com

[17] RCC Dam Project – mmmhydropower.blogspot.com

[18] Howard, T.R. (1982) Statistical analysis of embankment dam failure. Proc. 19th Annual Engineering Geology and Soils Engineering Symposium, Pocatello, ID, USA. p.1 – 17.

[19] ICOLD. (1995) Dam failures statistical analysis. International Commission on Large Dams (ICOLD), Bulletin 99.

[20] MWR. (1993) National inventory of reservoir dam failures. The Ministry of Water Resources of the People's Republic of China (MWR), Beijing (in Chinese).