

# International Journal of Innovative Research in Science, Engineering and Technology

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## Study on Dam Failure - A Review

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**ABSTRACT:** Natural disasters like earthquake, flood, rockslides and faulty design of dam affect on dam structure. Seepage may occur continuously. Deterioration of construction material and foundation is a slow process. Failure of dams occur because of overtopping, inadequate spillway capacity, excessive seepage across the body, alkali aggregate reaction, cavitations in energy dissipaters, stresses due to external and internal forces, 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. St. Francis Dam in U.S.A., Gleno dam in Italy and Malpasset Dam in France were failed due to foundation deficiencies. If precautionary measures are implemented in time, the damages can be forbidden. The continuous monitoring of a dam will ensure the early detection of any damages.

**KEYWORDS:** Seepage, Overtopping, Alkali aggregate reaction, Spillway

### I. INTRODUCTION

Dams are used for Water supply, hydropower generation, flood mitigation, Irrigation and recreation. Based on analysis 40% dams are failed due to foundation failure, 23% are failed due to inadequate spillway capacity, 12% dams are failed due to poor construction, 10% dams are failed because of uneven settlement, 15% dams are failed due to embankment slips of high pore pressure of defective material etc. There are around 55000 large dams constructed overall world, with aggregate storage capacity of approx 6500km<sup>3</sup> (Mc Cully1996) which obstruct half of the world's river. This shows seven fold increase in the standing supply of natural river water (Voersoesmarty et. al., 1997). Two third of the freshwater moving towards sea is controlled by dams (Naiman et. al.,1993).

### II. FAILURE CAUSES

The dam failures are observed as overtopping, inadequate spillway capacity, deterioration of concrete, seepage across body, excessive stresses due to external and internal forces, alkali aggregate reaction, erosion of surface of spillway, glacia and cavitations of energy dissipaters, excessive scour downstream of spillway and so on.

Reasons of the dam failure:

1. Foundation deficiency is one of the primary causes of dam failure. It may be related to the natural conditions of foundation and its treatment during construction. Uncontrolled seepage, Differential settlement, sliding, high piezometric pressures are common factors of foundation distress. Minor cracks may also indicate of foundation deficiency. Seepage causes internal erosion. The migrated particles from foundation may leave collapsible voids. Such potential weakness can be identified by examining geotechnical conditions in the reservoir. The Malpasset dam was built across Reyran river located on French riviera in the southern portion of France. Cracking noises were heard near the dam wall in 1959 but they could not be analysed due to technical inability. The dam breached on December 2, 1959 and entire wall collapsed into pieces and the dam suddenly broke from its foundation. Waves of over 40 meters started flowing across the nearby areas causing heavy structural damage. It was found that the failure of Malpasset Dam in France and Gleno Dam in Italy were occurred due to foundation deficiencies.

The St. Francis Dam was located in San Francisquito Canyon and built in 1926. Cracks started in the walls of the dam due to geological instability of canyon walls. They were taken care of but not completely as most of

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damages were considered to be normal by engineers and they did not decide to give time to that. The walls of the dam could not hold the water on 12 March, 1928 and it collapsed. 47 billion litres of water started flowing down the canyon. Waves of 43 meters in height started moving towards nearby area and caused great damage. Figure 1 shows images of St. Francis dam, USA (a) before failure and (b) after failure.



1(a)



1(b)

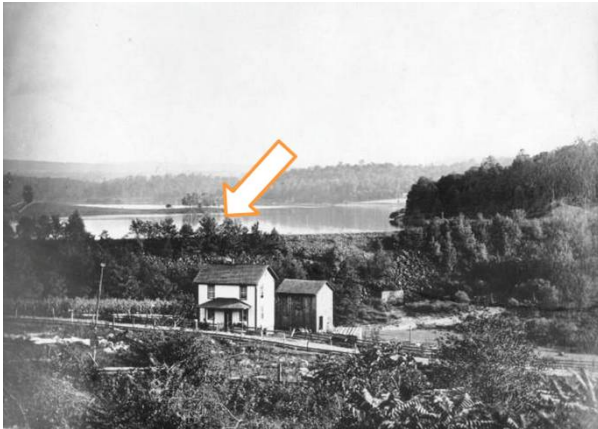
2. Excessive seepage across the dam causes failure of dam. The impoundment can be expected to increase substantially the percolation and pore pressure into the underlying formation unless seepage control facilities are installed. The seepage can occur through large portion in case of earthen dam. In case of concrete dam seepage flows would occur through joints, cracks induced to various causes, through foundation, through the material itself. The seepage water causes uplift pressure, erosive force, leaching of the lime from mortar, deterioration of the structure due to weathering which causes failure of the structure. So, monitoring and seepage control are essential to evaluate safety of the dam.
3. Excessive structural stresses due to external forces may lead to cracking, sliding or overturning failures. Different stresses need to be recomputed and suitable remedial measures taken for the safety of the structure. The Vajont dam is constructed across Vajont river in Italy among the tallest dam in the world. The area was often hit by minor earthquakes, but never affected by the dam. In Oct. 1963 when the reservoir was filled with water, an earthquake hit the area and landslide of about 260Mm<sup>3</sup> collapsed in reservoir. In 45 seconds, whole area immersed into the water and 50 Mm<sup>3</sup> of water were released from the dam in the form of 250 meters high wave which completely wiped out the nearby village. The dam failure caused due to sliding problems.
4. Mostly 23% of dams failure are due to inadequate spillway capacity. Overtopping is the common cause of failure. Notable flood stemming from inadequate spillway capacity in Oros in Brazil and South Fork in United states.  
Water of South Fork Dam in U.S.A. was often reported to be leaking at certain portions. To solve the issue, all the engineers did, was filling up the cracked portion with straw and mud. This was a temporary solution, but not a permanent solution. However, immense rainfall in May 1889 caused the bases of the dam to weaken. The capacity of dam was less to withstand arrived water so the dam collapsed and 20 million tons of water released on 21thMay,1889 and it ran several miles downstream. The total damage was estimated at \$17 million. Figure 2 shows images of South Fork Dam, USA (a) before failure and (b) after failure.

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2(a)



2(b)

5. For assessing safety in case of water storage we have to consider the possibility of sliding on slopes of reservoir and abutment. The Vaiont dam completed in 1959 and It did not suffer any serious damage. On October 9, 1963, 260 million cubic meters of rock broke off from the top of Monte Toc. It fell into reservoir of Vaiont dam, producing enormous waves of 50 million cubic meters of water. Flooding destroyed several villages and killed about 2000 people. Claystone and Shales are present in foundation of concrete dams, special precautions have to be considered. Figure 3 shows images of Longarone town, Italy (a) before landslide and (b) after landslide.



3(a)



3(b)

The Tigar Dam was originally constructed between 1913 and 1917 to provide irrigation and water supply source to Gwalior. The structure was made of rubble masonry interior placed with lime mortar and faced with staked masonry with cement mortar joints. The dam had vertical upstream face and 2:3 downstream slope. The dam was constructed on stratified sand stone with near horizontal bedding planes. Excavation for dam was limited to about 2 foot depth, although weaker zones in sandstone were excavated deeper and filled with concrete. No additional seepage control installed in dam foundation. On 4th Aug. 1917, water surface in the reservoir overtopped the dam by one foot from abutment to abutment. Estimated overflowing flows were 30000 cfs (ft<sup>3</sup>/s). During overtopping event two spillway monoliths were moved several hundred feet downstream resulting uncontrolled release of reservoir. These two monoliths stand today as a reminder of the dam failure.

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6. Erosion occurs on concrete surface of Spillway glacis and Energy dissipators due to cavitation. Surface should be smooth and regular but faulty construction may lead to erosion and cavitations problem. Initially this problem is not identified, but may lead to serious problems.
7. The dam may fail due to alkali aggregate reaction. The reaction between alkali in cement and certain minerals in aggregate cause complete deterioration of the structure. The alkali gel formed on absorbing moisture swells and develops pressure which cause distress in concrete. In Hirakud Dam in India, cracks were observed in galleries and sluices. The interior faces of sluices in some blocks were noticed to develop deformed shape due to local bulging, leading to difficulties in operation of the gates difficult. The visible clues to the dereriation include expansion, cracking of random pattern, gelatinous discharge and chalky surfaces.
8. Excessive scour effect at downstream side of spillway causes failure of dam. When a high velocity water flows over the unprotected riverbed downstream from the spillway, it may erode bed material and carry it either in suspension or as bed load further downstream. Excessive scour immediately below the spillway may endanger its foundation. At Islam weir which is located in Sutlez valley resulting of scouring destroyed a large portion of downstream apron and six bay of weir collapsed.
9. The deterioration is accelerated if workmanship is bad, low quality material is used or proper construction procedure is not followed. Ageing of concrete dam can be attributed to physical and chemical factors. The former related to change in forces acting on structure, including those caused by temperature variations. The latter is associated with infiltration in to dam of aggressive water containing inorganic acids, sulphates and certain other salts. Chemical reactions can result in leaching of the concrete. Soft water may attack on concrete causing serious deterioration within a few years. Bratsk dam in USSR, temperature variation caused cracking of upstream heel, opening of the expansion joint and danger of rupture of grout curtain. In 1895, failure of Bouzey dam was attributed to concrete deterioration.

### III. PRECAUTIONARY MEASURES

Precautionary measures are vital in preventing dam failures as it could cause mass destruction of lives and properties. Most of the failures occur because of inadequate maintenance. Therefore, regular monitoring and maintenance is necessary for dam safety. Spillway must be working efficiently, fractures in concrete must be grouted with fresh concrete, eroded slopes of the dam must be cured. Dam maintenance team should be provided awareness regarding the importance of monitoring activities and probable hazards due to negligence in maintenance.

### IV. CONCLUSION

Dam is an important hydraulic structure that stores water, which is used for domestic need, industrial need, irrigation purpose, electricity generation etc. Even though modern dams are constructed to last indefinitely, they are vulnerable to failure in the absence of periodic maintenance. Failure can be avoided by regular monitoring during pre and post construction periods. It is required to install modern instrumentation system for supervising dam maintenance activities.

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