How Dams Fail

There are different types of dams classified by the material and design used in construction. These differences influence how and why dams fail. A dam can be classified by its material, indicating whether it is earthen or concrete. Dam components can also include iron, steel or timber or a combination of any of the above.

The different types of dam design include embankment dams, gravity dams, arch dams and buttress dams. Embankment dams are generally made of semi-permeable natural materials such as rock or earth, while the remaining three types rely mainly on concrete.

The function of dams is to block the flow of a river creating a natural storage tank for the now trapped water. A functional dam needs to be strong enough to hold back its reservoir (the Three Gorges dam's massive reservoir is as big as Lake Superior and its normal pool level will reach an elevation of 175 meters) and it needs to be able to pass floodwaters through the structure during heavy rains and periods of increased run-off.[1]

To do this, dams have built in safety features called spillways, a channel or passageway that allows a controlled release of excess water, used to maintain safe water levels or to slowly empty the reservoir if the dam is cracked or failing.

If the spillways become blocked with debris, like silt, mud or trees, or if the spillway gates (the mechanisms controlling the spillway) malfunction and water cannot be released, there is a danger that the water level in the reservoir will rise higher than the crest of the dam and spill over. This is known as "overtopping."

A dam's foundation is crucial to the dam's stability. Just as with a house, a shifting foundation can cause cracking and failure. During an earthquake, for example, a dam undergoes the same stresses as any other structure. Cracks in a dam may indicate structural damage that can lead to collapse.

The US-based Federal Emergency Management Agency (FEMA) defines dam failure as a: "catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release. Here is a list of the main ways a dam can fail.

[1] Of course, meanwhile it needs to retain enough water to generate electricity (if it is a hydro dam) and storage capacity if it is a flood control dam.

Leading Causes of Dam Failure

Overtopping: 1/3 of all dam failures globally

Overtopping occurs when the level of a reservoir exceeds the capacity or height of the dam. This can be caused by an inadequate or dysfunctional spillway or by settlement of the dam crest (for an explanation of settlement, see foundation defects). Overtopping occurs when water levels rise rapidly and without adequate warning (for example, due to flashfloods, heavy rains, a landslide in the reservoir that creates a tsunami, or if a dam upstream collapses). The result can compromise the structural integrity of the dam or it can quickly erode the land on either side of the dam, in effect disengaging the dam from its river slope embankments. In earthen dams the main cause of failure is erosion caused by overtopping or a failed spillway. (Example of failure due to overtopping: Banqiao Dam)

Foundation defects: 1/3 of all dam failures

Defects can occur in the foundation supporting the dam. For example, the mere weight of a dam structure has an impact on the ground underneath. If this weight is not properly taken into account in the engineering of the dam, the ground underneath can settle unequally and compromise the foundation (imagine the leaning Tower of Pisa). Similarly, dams built on slopes must be properly engineered to avoid issues with instability or landslides. Any event causing the movement of a foundation, such as an earthquake, can also compromise a dam's foundation. The main cause of concrete dam failure is a problem with the foundation. High uplift pressures and uncontrolled foundation seepage can also compromise the dam's foundation. (Example of catastrophic dam failure due to foundation defects: St. Francis Dam)

Piping and seepage: 1/5 of all dam failures.

Embankment dams – which are generally semi-permeable – can be compromised when too much water seeps or leaks through the structure. Dam failure can occur when the structure becomes weakened from internal erosion, an effect referred to as piping. This can occur along hydraulic structures, spillways, conduits, or cracks. Such seepage or leakage can even be caused by an animal burrowing in and around earthen dams. (Example of dam failure due to piping and seepage: Kelly Barnes Dam)

Other reasons

Dams which are improperly maintained or built with inadequate materials or unsound design can result in structural weaknesses that lead to catastrophic dam failure. (Dam failure due to improper maintenance and structural weakness: Val di Stava Dam)

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ces: Hawker, Patrick, 2000. *A Review of the Role of Dams and Flood Management,* Thematic Review IV.4: An Assessment of Flood Control and Management Options, www.dams.org/
"Notable Dam Failures," Washington State Department of Ecology, 2007.

www.ecy.wa.gov/PROGRAMS/wr/dams/failure.html
"Why Dams Fail?" Federal Emergency Management Agency, 2006. www.fema.gov/hazard/damfailure/why.shtm
"Operations, Monitoring and Decommissioning of Dams Final Version," World Commission on Dams, November 2000, www.dams.org

Examples of Dam Failure

Dam/Reservoir	Location	Type	Year	Main reason	Death toll/Cost
Taum Sauk	USA	Concrete	2005	Overtopping	Damage avoided
Big Bay Dam	USA	Earthen	2004	N/A	100 homes destroyed
Folsom Dam	USA	Concrete	1995	Spillway	Damage avoided
Val di Stava Dam	Italy	Earthen	1985	Improper maintenance/ Design	268 people, €155 million in damage
Tous Dam	Spain	Rock-filled	1982	Insufficient spillway	20 people
Morvi River Dam	India	Earthen	1979	Overtopping	15,000 people
Laurel Run Dam	USA	Earthen	1977	Overtopping	40 ppl./$5.3 million
Kelly Barnes Dam	USA	Embankment Earthen	1977	Piping	39 ppl, $2.5 million
Teton Dam	USA	Earthen	1976	Foundation	14 ppl./ $1 billion in property damage
Banqiao Dam	China	Embankment	1975	Overtopping	200,000 people
Baldwin Hills	USA	Earthen	1963	Ground movement from oil extraction	5 people
Maupassant Dam	France	Concrete Arch	1959	Overtopping/ foundation	450 people
St. Francis Dam	USA	Concrete Arch	1928	Foundation	450 people
Austin Dam	USA	Concrete	1911	Foundation	87 people

For information on these and other dam failures, see:
*www.google.com/Top/Science/Technology/Structural_Engineering/Dams/Failures/
*www.dmoz.org/Science/Technology/Structural_Engineering/Dams/Failures/
*www.dha.lnec.pt/nre/portugues/funcionarios/papers/rmartins/Lives_2000.pdf
*http://cee.engr.ucdavis.edu/faculty/lund/dams/Dam_History_Page/Failures.htm