

# Overspill fusegates

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**A** system has been designed in France to increase the flood discharge capacity, and/or the storage capacity, of existing and future reservoirs. Several dams in France which previously had uncontrolled spillways have already been modified to incorporate the system; one case was described briefly last month (*WP & DC* June 1992, *World News*). Here we look at the development and design of the concept in more detail.

The control of floods is one of the most important aspects of dam safety. It accounts directly, or indirectly (allowing for the cost of gate supervision and maintenance or lost storage capacity associated with ungated spillways), for about one-third of the cost of an average dam. In addition, the high uncertainty factor concerning design flood estimates often leads to either an over-design of spillway capacity (which is a waste of money) or an inadequate design. Furthermore, it may not be known which of these two possibilities applies, except in the case of a very large catchment area.

The malfunctioning of gates is one of the main causes of failure for gated structures, and has been known to occur at much less than the design flood.

These problems can partly be overcome at some sites by the use of fuse dykes, where moderate floods are discharged by conventional spillways, and larger volumes (for example, 100 or 500 year floods) overtop the fuse dyke and wash it away to provide the necessary extra discharge capacity. Although cost-effective in many cases, this method is only feasible at a relatively small number of sites, and it puts constraints on the layout of the main dam. Although it prevents the destruction of the main dam if the gates fail to open in a major flood, it also releases a large flash flood downstream.

## Fusegate concept

The new system, known as the Hydroplus fusegate, derives from the idea of fuse dykes, but eliminates the drawbacks described above. It can be retrofitted quite easily and economically at existing ungated dams, and has the further possibility of increasing the reservoir storage capacity.

The fusegates are independent free-standing gravity units placed on the overspill sill crest. Their height can be up to about 75 per cent of the head on the ungated sill at full design flood discharge. This saves 75 per cent of the otherwise wasted volume of water. Moderate floods spill over their tops, but during large floods, they overturn as a result of uplift pressure and ensure the safe discharge of the extra flow volume (see Figure and photographs in *WP & DC*, June 1992). The spillway thus operates like an ungated structure during moderate floods, and as a gated one in the case of heavy floods. However, a major advantage is that the gates cannot fail to operate, as the concept is based on simple physical laws rather than an electrical system. Their structure is simple, and they have no moving parts.

## Design and operation

Between five and 20 units are typically installed, depending on the spillway size. Each unit stands on the sill and abuts against a low frame built into the crest. The fusegates, built of steel or reinforced concrete, have three main elements:

- the main structure, or bucket, has a labyrinth shape to

increase the crest length and reduce the depth of the overflowing nappe during moderate floods;

- the bottom chamber, usually built of reinforced concrete; and,
- the inlet well, arranged to admit water to the chamber only at a pre-set reservoir level.

The level at which uplift pressure is caused, following entry of water into the chamber, can be set individually for each fusegate.

Thus, when the headwater level is lower than or level with the top of the fusegate, it acts as an extension of the dam. Small to moderate floods spill over the fusegate unit, but the labyrinth sill increases the overspill length by a factor of about 3.

When a very large flood occurs, water enters the chamber through the inlet well after the pre-set level has been reached, and uplift pressure beneath the unit causes it to overturn about its abutment frame without affecting the adjacent gates, which can be set to operate at higher water levels. Once the flood has receded, the overturned unit or units can be re-installed on the sill, or replaced with new ones if they have been damaged.

There is no danger of the overturned units remaining on the spillway chute (and blocking it) as they are only stable at velocities of less than 3 m/s. They will be washed several tens of metres downstream.

The inlet wells are generally arranged so that no units overturn for less than the 50-year flood, which usually represents one-third of the design flood.

The margin of stability prior to the admission of uplift pressure and the shape of the inlet wells means that floating debris and waves have little effect on the level at which the fusegates overturn. This was verified both by theoretical studies and model tests. In cases where very thick ice cover or intense seismic activity could be expected, it might be necessary to reduce the height of the fusegates.

## Effects on spillway chute

The fusegate system aerates the nappe considerably, not only during moderate floods, but when discharging large flood flows as well, since non-adjacent units can be set to overturn first. This reduces the erosion risk normally associated with spillway chutes.

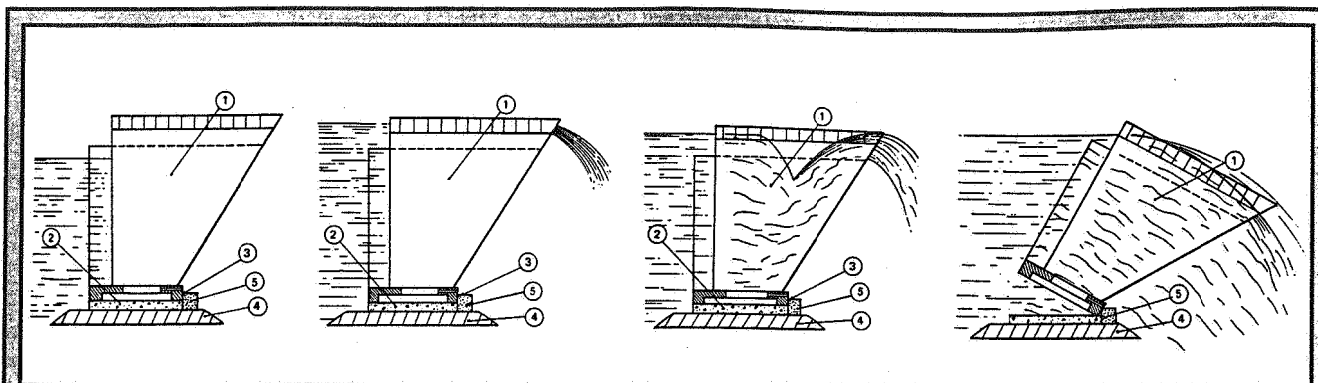
## Effect on downstream flow

The outflow curve is similar to the curve for an ungated spillway with its crest level at the top of the fusegates, but three times the length.

During moderate floods this is a natural consequence of the labyrinth shape. During larger floods, the fusegates overturn separately as inflow continues to increase, which is similar to the way many conventional gated spillways are operated; but even in this case, the outflow curve is very similar to that of a long overspill. There are two differences during very large floods:

- There is discontinuity in the curve as one of the units overturns, but this only occurs when the river has already reached one-third of its maximum flow or about 60 per cent of its maximum level. Thus the sudden rise in downstream water level caused by the increase in outflow only represents some 10-20 cm, which attenuates farther downstream.
- The recession period is prolonged by the time needed for the extra capacity provided by the fusegates to discharge through the gaps where the units have overturned. Condi-

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The concept and operating sequence of a Hydroplus fusegate: 1 = inlet well; 2 = chamber; 3 = vent hole; 4 = sill; 5 = abutment.

tions are those of an uncontrolled spillway, the length of which is equal to or less than the spillway crest.

The flood detention performance of a fusegate system (or of a gated spillway) is not as good as that of an uncontrolled spillway. This may make it necessary for the spillway capacity to be increased, compared with a corresponding ungated structure. This can be done simply and cheaply by lowering the sill and increasing the fusegate height.

## Application to dam types

Fusegates can be installed on most existing overspill sills to increase reservoir capacity, electricity generation or discharge capacity. They will fit all standard and curved crests. Modifications to suit multiple arch dams or morning glory spillways involve some extra cost.

The system could also be applicable for certain irrigation dams which are not completely filled each year. They would provide over-year regulation at very low cost.

The use of such gates for dams essentially used for flood control would reduce considerably the downstream flow for large floods (50 to 500 year return periods) with no change in the management of extreme floods.

The fusegates offer the same advantages for new dams as for existing structures, and in addition, the spillway sill can be built shorter and lower to reduce the cost of the chute.

Where a gated spillway is designed for very large flows, costs might be reduced and safety improved by having conventional gates over 20-50 per cent of the spillway length, and fusegates for the rest, so that these could operate if the conventional gates failed.

Fusegates could increase the storage capacity of many low irrigation dams, usually designed with uncontrolled spillways, by nearly 50 per cent, making otherwise uneconomic dams feasible.

They would also be an attractive option for dams designed solely for flood control, since the sill length could be shortened by a factor of two or three, with associated savings on the cost of the chute and greater freedom for selecting the location of the dam.

## Experience with the system

Hydroplus fusegates have so far been installed at three dams in France, and a further project is underway.

The first dam to be modified to incorporate the system, in April/May 1991, was the Lussas irrigation dam in Ardèche, near Valence. Its normal storage capacity was  $320 \times 10^3 \text{ m}^3$  and it is equipped with a lateral spillway. The design flood was  $250 \text{ m}^3/\text{s}$  (1000 years return period). A 35 m length of the sill was equipped with 10 fusegates, each gate being 2.15 m high and 3.5 m wide. The extra reservoir

volume gained was  $130 \times 10^3 \text{ m}^3$  (or nearly 40 per cent) and the spillway discharge capacity was increased by 15 per cent.

In September 1991 the storage capacity of the Gouyre earthfill irrigation dam, near Toulouse in southwest France, was increased by  $500 \times 10^3 \text{ m}^3$  (about 20 per cent). This project was more unusual, as the spillway was of the morning glory type. A lip of the spillway was fitted with 12 monolithic concrete fusegates, equipped with galvanized steel wells.

The third scheme was the 12.5 m-high Saint Herbot masonry dam, near Brest in Brittany. Here five fusegates were installed in March/April 1992, to replace 10 old wooden gates (with a discharge capacity of  $10 \text{ m}^3/\text{s}$ ), and to bring the spillway into conformity with required safety criteria ( $90 \text{ m}^3/\text{s}$ ). In this case the level of the reservoir was kept at its original elevation. A demonstration of the operation of one of the fusegates at this scheme on 22 April was described in *WP & DC* last month. On this occasion an artificial flood was created when  $16 \text{ m}^3/\text{s}$  was released from the St Michel reservoir upstream.

## Potential for the future

It is estimated that nearly  $100 \times 10^9 \text{ m}^3$  of storage capacity is at present wasted throughout the world at uncontrolled overspill dams. Fusegates could not be added at all of them, but a reasonable estimate for the potential savings offered by the system is nearly  $50 \times 10^9 \text{ m}^3$ , at a very much lower cost per cubic metre than the usual cost of storage. At irrigation and water supply dams this would not involve any extra expense for the distribution system.

Fitting fusegates at existing hydroelectric dams would not normally improve the maximum installed capacity, which would be dictated by the machinery, but annual generation could be improved by the increased head and reservoir capacity.

Retrofitting existing structures provides an opportunity to improve operating conditions without increasing the environmental impact. For the majority of new dams, it is an economical and safe concept, either on its own or sometimes in combination with conventional gates in the case of very large flows (say, more than  $5000 \text{ m}^3/\text{s}$ ).

About 50 dams are under study throughout the world with fusegate heights ranging from 1 to 8 m and flows of up to  $30\,000 \text{ m}^3/\text{s}$ . □

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