Study on Environment-Friendly Energy Dissipator of Hydropower project

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Abstract. Due to the increasing requirements for environmental protection in hydropower projects, the design of energy dissipator needs to fully consider its environmental impact, to minimize the impact of flood discharge atomization, avoid supersaturated total dissolved gas, and reduce flow site vibration. And it's trying to achieve a simple structure, convenient construction, investment savings, to reduce resources and energy waste. This paper discussed the environmental impacts in the design of energy dissipator in hydropower projects, pointed out the characteristics of “environmentally friendly” with putting forward specific requirements for hydropower projects. Several common-used environment-friendly Energy dissipators were proposed and analyzed in this paper, which can be reference in engineering design practices.

1. Introduction
Most of China’s water resources are concentrated in the south-western region. A large number of high dams have been or are under construction. These projects generally have the characteristics of high water level, large water flow and narrow river valley. With the concept of building a beautiful China gradually deepening into the hearts of the people, the requirements for environmental protection of hydropower projects are getting higher and higher, and the various environmental impacts caused by the design, construction and operation of hydraulic projects are receiving more and more attention from all parts of society, with higher requirements for the construction of hydropower projects[1].

For most projects in the south-western region, due to large discharge and flood discharge power, narrow river valleys, steep slopes, the layout of the hub and the design of flood discharge and energy dissipation buildings are greatly limited. There are great difficulties in terms of scheme selection, overall layout and structural design. The design of flood discharge and energy dissipation buildings not only affects project operation safety, engineering investment and efficiency, but also has a great impact on the dam site area and surrounding environment:

① Flood discharge atomization caused by flood discharge and energy dissipation and serious river channel erosion are not conducive to slope stability. For example, Longyangxia, Lijiaxia, Ertan and other projects have caused landslides of different scales due to flood discharge atomization[2].

② The downstream water flow produces supersaturated dissolved gas and causes fish to die. The flood discharge of the Three Gorges and Xiluodu hydropower stations leads to supersaturated dissolved gas in the water body, leading to the problem of dead fish in the downstream river.

③ The turbulence of the flood-discharging water body caused the flow induced vibration of the energy-dissipation zone structure and the surrounding sites vibration. The Xiangjiaba Hydropower
Station encountered the problem of flood induced site vibration in the design of flood discharge energy dissipation. The secondary hazard caused by these flood discharges and energy dissipation has restricted the development and construction of hydropower projects to a certain extent.

This paper discusses the environmental impacts in the design of flood discharge and energy dissipation buildings in hydropower projects, points out the characteristics of “environment-friendly”, and puts forward specific requirements according to the actual situation of hydropower projects, and comparing several commonly used environmental friendly flood discharging buildings.

2. Features and requirements of environmentally friendly buildings
The so-called "environmental friendly" can be understood in a broad sense to reduce the generation of various wastes by reducing the consumption of resources and energy during the life of the building, and to achieve the project of symbiosis with nature. In the narrow sense, it means that planning and design are sufficient. Consider and take advantage of environmental factors, projects that have the least impact on the environment during construction and operation. As a traditional clean energy source, hydropower is an important part of China's implementation of sustainable development strategy and the construction of beautiful China. However, it will inevitably have a certain impact on the environment during construction and operation. Therefore, it is necessary to any project fully considering its environmental impact and try to achieve environmental friendly purposes at the design stage.

Flood discharge and energy dissipation design as one of the key points of hydropower engineering design, its environmental friendliness is reflected in the following aspects:

(1) Small impact of flood discharge atomization
The design of flood discharge and energy dissipation buildings should control the flood discharge atomization range and fog rain intensity as much as possible, and take necessary engineering measures to reduce the impact of flood discharge atomization on the construction slope and natural slope.

(2) Avoid supersaturated total dissolved gas (TDG)
In the design of flood discharge and energy dissipation scheme, the total dissolved gas (TDG) caused by flood discharge and energy dissipation should be avoided as much as possible to reduce the impact on aquatic ecology.

(3) Reducing flow vibration and site vibration
The flood discharge and energy dissipation scheme should avoid direct erosion of the construction slope and natural slope of the energy dissipation zone, reduce the flow induced vibration of the energy dissipation zone structure, and avoid causing vibration of the surrounding sites.

In addition, under the premise of ensuring the safety of the structure of flood discharge and energy dissipation buildings, the design of flood discharge buildings should be as simple as possible, convenient in construction and economical in investment, so as to alleviate resources and energy waste.

3. Study on environment-friendly structures for flood discharge and energy dissipation
With the gradual emphasis on environmental impact and the development of flood discharge and energy dissipation technologies, more and more designs for flood discharge and energy dissipation begin to pay attention to the environmental impacts, and they have some certain environment-friendly characteristics. The following examples which show the characteristics of the environment-friendly structures for flood discharge and energy dissipation are listed for reference in engineering design.

3.1. Energy dissipation by stepped overflow dam crest
The overflow surface of the flood discharge structure is designed as a stepped one (Figure 1) and forms the energy dissipation type in the end. It can dissipate energy due to the horizontal axis’s swirling, collision and aeration formed by the flow of water through the stepped overflow surface. The dam surface stepped energy dissipation can be used alone as well as in combination with a stilling pool and a flaring gate pier.
3. The outstanding features of stepped energy dissipation are the large frictional resistance and high aeration of the overflow surface which makes high energy dissipation rate to greatly shorten the size of the downstream energy dissipator, and it can generally shorten the length of the stilling pool by 10%~30%. When the stepped energy dissipator is used alone, it is more suitable for designing medium dams and low dams with a unit width flow less than 20\(\text{m}^3/\text{s} \cdot \text{m}\). It is also gradually applied to the large unit width flow or the high dam projects combining with a flaring gate pier. The energy dissipation area of the stepped energy dissipation on the dam surface will not generate flood discharge atomization when used alone. It will have little impact on the downstream river channel and the mountain body nearby, and generally will not cause the flow vibration or site vibration of the surrounding mountain body. However, the application range will have some certain limitations when it is applied to RCC dams with small unit width flow and low height.

Figure 1. Energy Dissipation by Stepped Overflow Dam Crest

3.2. Energy Dissipation in Plunge Pool

In the existing large-scale hydropower projects, there are many energy dissipation applications using the scheme of the pick-up flow and plunge pool. This kind of energy dissipation type has strong adaptability, effective energy dissipation, and high security for flood safety, but there are also some problems such as flood discharge atomization and the erosion of slope. Some protective measures will be taken in the projects.

The plunge pool mainly uses the submerged hydraulic jump to dissipate energy. The oblique flooding impinging jet in the plunge pool is a mixed structure of the jet mainstream zone and vortex zone. The boundary area between the mainstream area and each macro vortex area is a layer of strong turbulent shearing action zone, and the mainstream in this area is continuously annihilated by strong turbulent shearing and diffusion, so the effective mechanical energy (kinetic energy) is continuously eliminated\(^3\). So it is the main area of the jet effective mechanical energy to eliminate the brake, the energy dissipation rate can reach more than 70%. The flow state in the plunge pool is shown in Figure 3.

Figure 2. Stepped energy dissipation and flood discharge building of Moruo hydropower plant

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In engineering practice, in order to alleviate the turbulence of energy dissipation in the plunge pool and the impact of flood discharge atomization on the slope, the plunge pool behind the dam generally needs to adopt slope protection measures and they are generally divided into fully lining plunge pools and partial lining ones\cite{4}\cite{5}. Those two forms are shown in Figure 4 and Figure 5.

In energy dissipation, the way of building a plunge pool is widely used and the mechanism and protection technology are relatively mature. However, there are some problems such as flood discharge atomization, flow-induced vibration, and super-saturation of total dissolved gas in downstream water bodies\cite{6}. Engineering measures like slope protection are needed to improve its environmental friendliness.
3.3. No collision in dam outlets for energy dissipation
For high arch dam, the collision to dissipate energy in the air can produce serious flood discharge atomization. Therefore, the type of deep-hole water flow without collision is used in the design of the flood discharge energy dissipation in some projects. There are two methods, one is the normal middle hole outlet with wide gap pulled apart from each other as much as possible, but it is difficult to achieve because the valley is quite narrow. Another one is that the deep hole of the high arch dam is made of shrinking energy dissipator, such as flaring gate pier and the slit-type bucket that use the characteristics of the shrinking energy dissipator to shrink the water flow to obtain a narrow and long drain tongue flow state. The water tongues are inserted and dropped from each other to realize energy dissipation without collision in the air.

The Jinping Hydropower Station uses flaring gate piers in the surface hole and slit-type bucket in the deep holes\[7]. So the releasing water tongues are narrow and long flowing. They are interspersed in the air without any collision to realize the goal of no collision in the deep water tongue, as shown in Figure 6.

![Figure 6 Typical flow pattern of water plunge pool](image)

The slit-type bucket without collision for energy dissipation reduces the intensity and range of flood discharge atomization, and has less impact on the environment. It is suitable for high arch dam projects in narrow valleys, but the leakage capacity of the orifices will be reduced by the influence of narrow slits. Also, the impact damage of the lower water tongue on the bottom of the plunge pool should be it should be avoided in the design.

3.4. Swirling energy dissipation
The swirling energy dissipation refers to the purpose of dissipating energy by setting a rotation device and other measures to cause the water flow to generate a rotary motion in the flood discharge tunnel. The swirling energy dissipation generally consists of four parts: the water diversion channel, the rotating water flow generating device, the energy dissipation section and the water outlet. The high-speed rotation of the water flow utilizes the turbulence, cutting action and vortex to eliminate water flow energy between the water flow layers. At the same time, the aeration of the swirling flow is used to change the water flow into a two-phase one, which increases the gas-water turbulence intensity, thereby effectively eliminating the flow energy.

The effective energy dissipation zone of the swirling energy dissipation is concentrated in the swirling hole, and there is no flood discharge atomization, which has little influence on the slope of the construction area, but the discharge capacity of the swirling energy dissipation is affected to some
extent, and the swirling flow. The aeration in the hole also easily causes problems such as supersaturated total dissolved gas in the downstream water body.

4. Conclusion

(1) With the increasing requirements for environmental protection in hydropower projects, environmentally friendly hydropower projects will gradually become the focus of future research, and the hydraulic engineers need to pay enough attention in the design, construction and operation of hydropower projects.

(2) Environmentally friendly flood discharge and energy dissipation building designing process need to fully consider its environmental impact, try to achieve the minimum impact of flood discharge atomization, avoid supersaturated total dissolved gas and reduce flow vibration and site vibration and try to achieve the goal of simple structure, convenient construction and less investment to reduce resources and energy waste.

(3) The stepped energy dissipation of the dam surface, the energy dissipation pond, the collision-free energy dissipation through dam body flood hole and the swirling energy dissipation all have certain environmentally friendly characteristics, but there are also certain shortages, which need sufficient research and argumentation based on the actual project to select the appropriate design.

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