OPERATION AND MAINTENANCE OF INFLATABLE GATES EXPERIENCES AT GERMAN WATERWAYS

by

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1. INTRODUCTION

Due to their age several weirs of the German Federal Waterways have to be replaced by new hydraulic structures. For numerous weirs simple configuration and expected efficiency operation gave reason for a design as inflatable gates. This technology once used to be new in the German Federal Waterways network. The current experience in operation and maintenance of these inflatable gates from now over 10 year allows the conclusion to establish more of this gate typ.

2. FUNDAMENTAL ASPECTS

The earlier projects were based after a long phase of internal discussions, followed by tests and examinations to face the criticism that went along with that - in Germany – rare technique. Cost analysis taken in the early part of the planning process showed that choosing an inflatable gate type is much more efficient than building a steel gate. The projects are mainly determined to control the water level for navigation. Due to the fact that usually the gates have to operate in cooperation with hydro power stations, the water level management has to cope with that facility, sufficiently fast and accurate. Therefore, the inflatable gates are chosen as water-filled type (Fig. 1).

Figure 1: Weir Marklendorf - first inflatable gate at German Waterways

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3. OPERATION & MAINTENANCE AT GERMAN WATERWAYS

The Water-filled rubber gates, which are only used in German Waterways, require a below ground pump and piping room and a larger civil engineering building complex. Therefore it must be insured that there is enough space to enter the rooms and allow maintenance and inspection works (Fig. 2). Nevertheless size of the control house is approximately 5% of the global project costs. The recommendation is not to take this part of the cost of the project too much into focus. The same is to say about the installation costs.

Figure 2: A look into the machine room

Like for every modern adjustable gate construction, inflatable weir gates needs to be driven and controlled by a system that is able to work automatically. The arrangement of controllers, valves, instruments and sensors is controlled by the on-site installed software (PLC). For example, the sensors of the piezoelectric pressure cells record an increase of the reference water level upstream of the dam. The software determines that a discharge of medium is necessary. The valves are “allocated” to be open. Hence, the control system manipulates the discharge. For all projects a remote control setup is requested to supervise and frequently to adjust the gate. Video surveillance needs much higher standards. Therefore there is no intention for the installation at German Waterways.

Concerning the regular operating procedures it could be concluded, the requirements are like usual weirs. An inflatable gate has two or three modes of operation: manually, automatically and sometimes remoted. Operating for exceptional and irregular situations is depending on the location of the dam, conditions like prolonged periods of flood or ice. It must be assured that the inlet piping and the monitoring well do not freeze. A heating system may be necessary.

In general, an Operation and Maintenance Manual will be provided by the manufacturer of the system. Beside the presentation of the operations, the manual explains the inspection and the maintenance issues. Both are aimed at structural examination and evaluation the membrane, the fixing system and the entire functionality of the weir. Just like other types of weirs, inflatable structures have components requiring inspection in a standardized way. Regular components of the superstructure and the mechanical and electrical equipment as well as their check of functionality should also be part of routine inspections.

Regular inspections and maintenance will lead to a conclusion concerning the eventual replacement of the rubber gate near the end of its lifespan.

The rubber membrane has different performance characteristics than a steel gate. This requires a different inspection protocol. The main goals of the inspection of a rubber membrane are the following:

- Abrasion of a rubber bag body.
- Aged deterioration of a rubber bag body
- Damages caused by debris and rolling rocks.

Once damage is identified during inspection (Fig. 3), the rubber membrane should be repaired. There is a large collection of repair tools offered by the manufactures. Hence inspections and maintenance are very significant for inflatable structures. Inspection reports should be catalogued and stored at the dam site if possible.

Figure 3: Inspection of a rubber gate

Preventive and corrective maintenance measures should be carried out to keep a rubber gate in effective operational condition as long as possible. Maintenance requirements for a rubber gate are significantly different as for a hydraulic steel structure gate. The rubber membrane is generally considered to be almost maintenance free except for occasional repair work as discussed below. There are no painting requirements or corrosion issues. There are no moving parts. The mechanical and electrical equipment will require periodic maintenance, but these components are fairly standard such as compressors, piping, and pumps. The primary interest lies on the aging during lifetime of the membrane. While the rubber is aging, the membrane loses strength.

As a conclusion, inspections and maintenance of a rubber gate is normally limited to visual inspection, functional testing plus - if indicated - fixing any leaks and making repairs to the bladder. The required maintenance activities of the field service personnel are generally lower than a steel gate. Hence, maintenance costs of inflatable gates can be considerably lower in comparison with the conventional steel gates.

Honestly there are cases of membrane or bladder damage. This includes delamination of the surface due to age or wear. Normally, cracks and in particular a limited hole in the membrane does not require a complete replacement of the rubber gate. The fiber-tissue in the membrane is responsible for the remove of each force in two-dimensional ways. For that reason a damaged area is supported sufficiently to withstand certainty small damage effects (Fig. 4). Hurts in the joints must be monitored with significant attention. A few repair works has to be made in the dry status. Thus the maintenance should be done during the low water period or in periods while placing the cofferdam structure. Replacement shall be executed by referring to the inspection records and checking for malfunction of equipment, damages of parts, aging of parts etc.

Figure 4: Repair Patches on a rubber membrane

4. CRITERIAS FOR THE UPCOMMING PROJECTS

The durability of a rubber bag varies in accordance with operation conditions (repetition fatigue due to the frequency of inflation and deflation) and environment at the site (deterioration by ultraviolet rays and the heat aging). Long-term experiences, especially from Japan, show that rubber gates can operate satisfactorily more than 30 years. The initial safety factor used for design of a rubber bag considers the lifetime at that range. Depending on the location and application, the rubber membrane is exposed to different water conditions, temperature extremes and loading conditions. As a general rule, it can be said that after two decades of use the membrane needs to be looked at more closely and inspection intervals are shorter.

Apart from the maximum values worldwide installed inflatable gates shows, that for 88% of the installations the height is less than 3.0 m, for 70% the span width is less than 30.0 m. These average values can generally be considered as typical dimensions of inflatable gates, while the maximum values indicate what is feasible at the moment. In general, inflatable gates are most appropriate for wide spans with a small number of piers, which makes them relatively unobtrusive in the landscape.

With regard to the number of applications it can be concluded that inflatable gates are a proven technology up to a certain limit. It is easy to imagine that setting a limit value for the height of inflatable gates even with proven technology is difficult. In general, the inflatable gate technology is proven up to 3.0 m by a very large number of installations. Up to 5.0 m there are still quite a number of gates with good experiences. For comparison, the application range of the Japanese standard for rubber gates is limited by a height of 6.0 m. Since 1978 this standard gives a solid base for the design and material requirements. Most of the meanwhile realized weirs have a width length of more than 20 m and heights up to 3.4 m. The weir infrastructure is designed as a standard concrete construction and generates ten times higher costs than the membrane itself. The equipment (clamping, pipes, valves, pumps, etc.) were around

half the costs in comparison to the membrane, similar is the electromechanical equipment. Yet the permanent maintenance procedure and the dry docking every 6 years are easy to realize by the owner's maintenance crew.

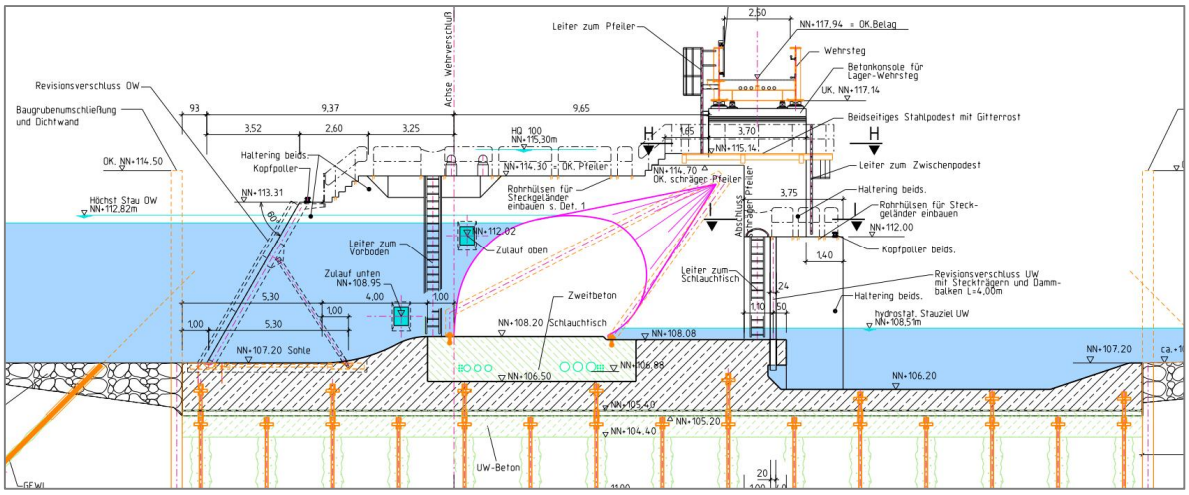

Figure 5: New project inflatable gates at the Main River

5. CONCLUSIONS

In recent years, the technology of inflatable gates has been improved and standards have been adjusted. Today, inflatable gates are an interesting alternative to standard steel gates, enabling savings to be made on the capital spending and maintenance costs, in particular on sites where these gate types are adapted to existing weir structures. An increasing benefit of this technology can be observed and leads to a "standard technology".

The experiences from the operation since the first German projects are in service are totally satisfying. The membrane is unharmed and fully in function, the expected life time of the membrane now is 30 years. Up to now there is no need to change the strategy. Following the above shown criteria, the German Water and Shipping administration sets up a standard for 10 upcoming projects for smaller rivers like Havel (near Berlin) and Lahn (near Frankfurt). But it also will be used for larger dams in rivers like Main – also Frankfurt - and Neckar – in the area of Stuttgart and Heidelberg. How to recognize, the projects are spread all over Germany.

References

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