Uplift Forces on a Hydromatrixâ-Module.

Reinhard Prenner, PhD

University of Technology Vienna, Institute of Hydraulic Engineering

Volker Kienberger, PhD

VA TECH HYDRO GmbH & Co

E-mail: Reinhard.Prenner@kw.tuwien.ac.at, Fax: +43-1-504-5928

Abstract

The following paper concerns the experimental investigation of hydrodynamic forces on a so-called "HYDROMATRIXâ-Module" during different underflow conditions. This mobile module is shifted in place of the stoplog slots in a tainter gate bay of an existing run-of-river project – which only currently serve water level control for navigation - to generate electrical energy. Apart from this use, the module also has to fulfill the functions of stoplogs in emergency situations. For this purpose it must be able to sink into the bay flowed through by flood. In order to determine the downpull forces on this module during flood conditions, a hydraulic model was built to a scale of 1:12.5. For this case a short section of the module was modelled in plexiglass which consists of 3 bulb turbine-axes in breadth and 2 turbine-axes in height. The investigation shows different underflow conditions in dependency of the position of the downstream level which influence the development of the hydrodynamic forces essentially. The results of the experiments were depicted in a diagram depending on downstream level, total lift forces and different steady lowering position of the module. Maximum downpull forces can also be easily determined for every gap of the throughflow opening of the module by these diagrams. Influences of different underflow conditions will also be described and evaluated.

I. INTRODUCTION AND AIM OF THE INVESTIGATION

General: The HYDROMATRIX®-Module (Fig. 1) is a new concept of electric energy production by run- of river powerplants which was developed by VA TECH.

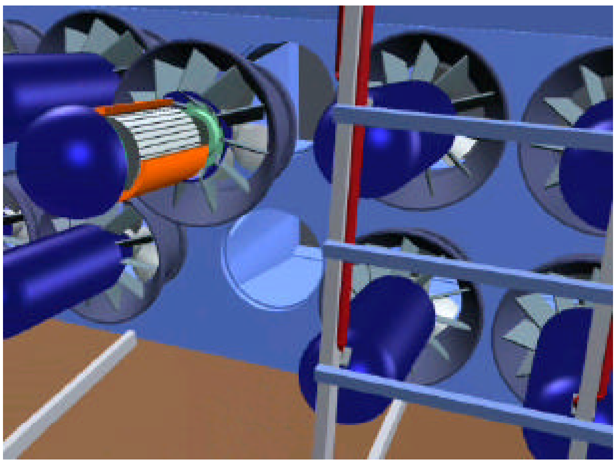

Fig. 1: Computer animated view on a HYDROMATRIX®-Module [1]

It basically consists of a compact arrangement of bulb turbines including trash racks, draft tubes, rooms for HPU, electric switchgear and control systems (Fig. 2).

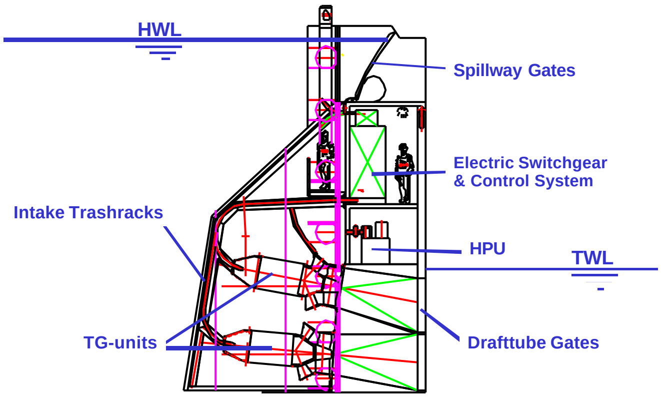

Fig. 2: HYDROMATRIX®-Module Typical Cross Section [2]

This module is a moveable construction, which can be raised out of the water – a facilitation in case of repair or revision - and even has to be removed at flood discharges. Such HYDROMATRIX®-Modules can be installed in existing dams (Fig. 3), usually in spillways, but even in sluices in shiplocks as well as in intake structures of irrigation systems.

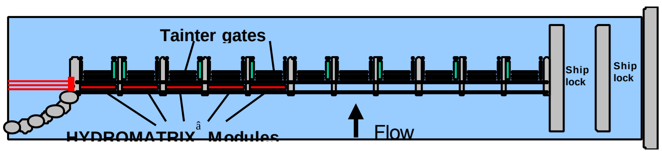

Fig. 3: General layout of HYDROMATRIX®-Modules in bulkhead gate slots of the tainter gate bays [2]

The construction is well adaptable and on the one hand easy to produce in comparatively short times. On the other hand there is no need for a powerhouse, which often requires expensive foundation solutions at geologically difficult grounds. Those essential advantages of HYDROMATRIX®-technology enable the owner to produce ecologically beneficial hydroelectric power projects at extremly low costs even after the erection of a dam.

Problem: A 30 year old dam on Ohio River, USA – erected for navigability and regulation of water level – will be equipped with HYDROMATRIX®-Modules (Fig. 4).

Fig. 4: Shiplocks and Dam on the Ohio River [1]

Modules will be installed in some of the tainter gate bays of the dam and will accomplish – besides the generation of electric energy – the function of emergency stoplogs. In this case they have to be lowered into the flood discharged bays (Fig. 5).

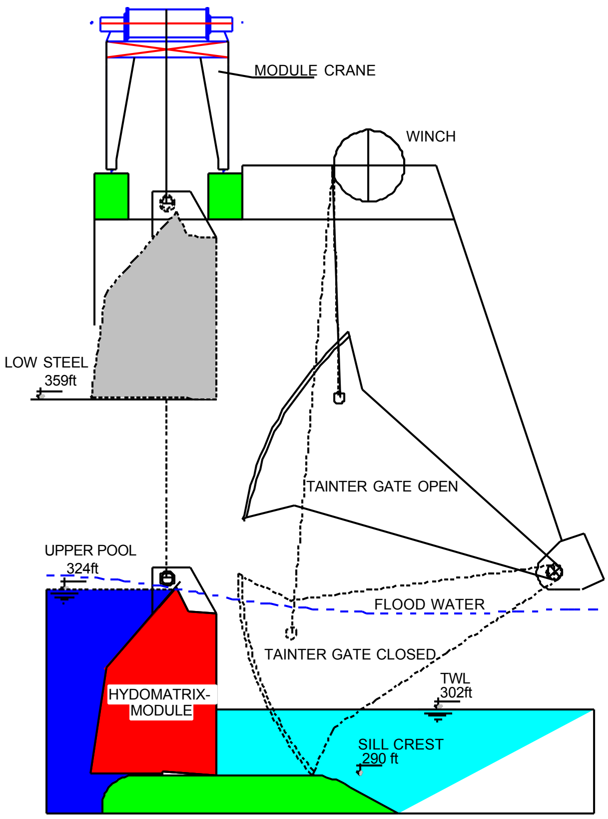

Fig. 5: Cross section view: General arrangement of a HYDROMATRIX®-Module in bulkhead gate slots of a tainter gate bay in lifted and lowered position

This condition can occur by a wedging or only partial lowering tainter gate. Normally the downpull of the module takes place with a fully closed tainter gate by balanced upper reservoir level. Due to the complicated structure of the module an exact computational determination of the downpull forces during underflow conditions is not possible. In case of exceeding a permissible amount of the hydrodynamic forces this fact would be a projectkiller.

For this reason, there are not only scientific, but also economic motivations to investigate the behavior of the HYDROMATRIX®-Module during emergency downpull scenarios accurately. To clear those questions the customer decided to carry out hydraulic model tests.

II. Basic Aspects - Description of Underflow Conditions

A series of scientific studies and corresponding publications on downpull forces acting on gates with underflow exists [3, Naudascher,1991]. Essentially downpull forces depend on gate-lip geometry as well as on downstream waterlevel.

Downpull can be calculated with the help of experimentally ascertained downpull coefficients, which were determined for relative gate openings at various gate geometries. However, the studies cannot be drawn up to estimate quantitative influences of those hydrodynamic forces on the given complex structure.

The specified distinctions between free-surface flow and submerged flow could be observed at the actual studies on the matrix module, too. Particularily, depending on tailwater level, two types of underflow were observed:

-Type of underflow 1: Low tailwater-level – discharge occurs as a free jet downstream the bottom seal (upstream end of draft tube). Pressure respective downpull arriving from flow around all construction elements upstream of the seal plane (trash rack, generators, distributor cone etc.) cause an increase of hydrodynamic uplift forces (Fig. 6).

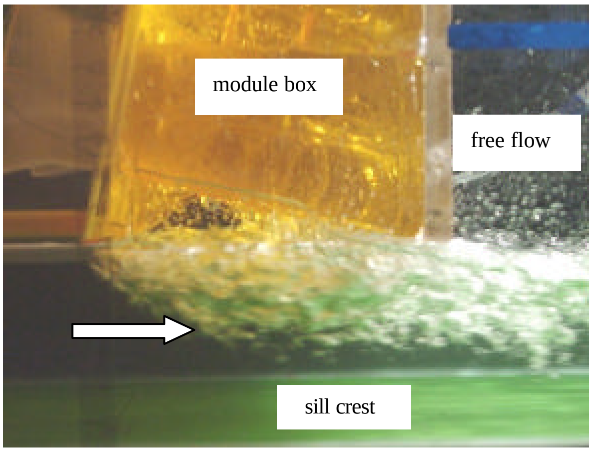

Fig. 6: Type of underflow 1

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ANDRITZ HYDRO GmbH
Lunzerstrasse 78
A-4031 Linz, Austria

Phone: +43 (732) 6986-0
Fax: +43 (732) 6980-2554
Hydromatrix@andritz.com