Technical surveys of dams by Scientific Divers – in-situ investigations and their implication

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ABSTRACT

Scientific Diving is a well-established approach in bio- and geosciences. Typical questions are the in-situ-measurement of water qualities, subaquatic slope-stabilities or geochemistry of sediments (waste disposal). Complex in-situ-measurements and targeted sampling or long time monitoring are assessed. Combined with detailed high-quality photo-/video-documentation, a reproducible workflow is applied, making the situation underwater accessible to non-diving engineers. This interdisciplinary approach comprises sound methods for technical surveys on dams (dam inspection, damage documentations).

For risk-assessment, the establishment of standardized-testing-procedures, as are applied for the survey of bridge buildings and in structural engineering, are proposed. In Germany's national standardization, these procedures are included in DIN 1076 or RI-EBW-PRÜF. Applying these standards to underwater-locations, a detailed evaluation of the technical state or damages is derived. An evaluating grade for each construction element can be given, based on the three major aspects stability, safety and durability. The summary of all documented issues provides a total grading on the condition of the building, being an objective and comparable value for further procedures or decisions. Advantages of "Scientific Divers" in contrast to "Commercial Divers" or ROVs are their scientific expertise and precise handling of analytics. Investigations of external impacts on the dam (biofilms, corrosion) infer specific preventing methods.

1. INTORDUCTION

1.1 Generals

In addition to barrages and their operational technology, the structures of special hydraulic engineering also include bridges above flood reliefs, inlet structures, tunnels, troughs with spillways, support structures, as well as slope stabilisation and rock consolidation in the vicinity of these edifices and installations.

Frequent structural investigations with subsequent maintenance and reconditioning are imperative to ensure operational reliability and stability. The German standard DIN 1076: “Ingenieurbauwerke im Zuge von Straßen und Wegen – Überwachung und Prüfung” (“Engineering structures in connection with roads; inspection and test”), warrants monitoring and testing of civil engineering structures based on consistent tests and evaluation principles. The damages and defects regarding a structure are assessed according to the following criteria: stability, safety and durability. Within a test cycle, various types of tests are performed including in-situ inspections of all statically constructed components.

In Germany, only certified construction inspectors with an academic degree in civil engineering and special training have the permission to carry out these structural investigations.

A focal point of structural investigations regarding special hydraulic engineering is the in-situ ascertainment and documentation of the damage. Therefore, the accessibility of submerged or high altitude components is a particular challenge.

If damage detection at high altitudes is required, the construction inspector uses the underbridge-inspection-unit or high-altitude safety technology to check for defects in-situ (Figure 1). However, the in-situ inspection of submerged part of a construction is a challenging task which necessitates special trained scientists or engineers being able to work under water.

Figure 1: Technical inspection at high altitudes with an underbridge-inspection-unit.

1.2 Current methods

Today, many investigations are carried out by indirect methods such as video-documentation by ROVs (remotely operating vehicle) or measurements from the water surface. These methods are useful tools for locations which cannot be reached safely by humans due to contaminations or limited space. Nevertheless, they are not able to replace the testing engineer at the location of the damage.

Another approach is the underwater work of commercial divers, which offer a variety of underwater services. Their central knowledge includes many fields of technical work, such as cementing, welding or parting. In contrast, any scientific investigation is highly recommended to be carried out by Scientific Divers rather than commercial divers.

2. SCIENTIFIC DIVING IN GENERAL

Scientific Diving is a well-established tool in eco-, bio- and geosciences or archeology. The safe and effective performance of underwater work respecting fundamental topics of scientific work and quality management necessitates special training. To be certified as Scientific Diver, scientists must pass a complex training (cf. Merkel et al., 2009 and 2013). The courses include theoretical education on all scientific fields where Scientific Diving is applied. Furthermore, practical pool-training as well as scientific work in lakes or oceans is part of the certification. Final examination happens during a diving expedition with qualified aquatic research including a project-based report or publication. After passing all courses, the applicant is certified by the world underwater foundation CMAS as “CMAS Scientific Diver” or “CMAS Advanced Scientific Diver” depending on its prequalification. Degrees as “CMAS Scientific Diving Instructor” and “CMAS Scientific Diving Instructor Trainer” can be awarded also. The certificates can exclusively be given by CMAS Scientific Diving Centers (located in Brazil, Germany and Spain).

A typical field of underwater research and work is the assessment of water qualities by in-situ-measurement. Central points are the undisturbed sampling of distinct strata or of local anomalies. The sampling of different phases (e.g. gas / water; Merkel et al, 2010) and mapping of groundwater discharges underwater are common tasks, too (cf. Stanulla et al., 2015).

Furthermore, geotechnical investigations are in focus of Scientific Divers. The stabilities of subaquatic slopes or the geological mapping are only two typical examples. Especially sampling and in-situ investigation of sediment samples for geochemical analysis is a modern approach for waste disposal planning (geochemical declaration, depositional classes).

Scientific Divers can assess complex in-situ-measurements and targeted sampling or long time monitoring. A wide field of scientific topics, including chemistry, thermodynamics, microbiology and many more, is covered. Combined with detailed high-quality photo and video documentation, a reproducible workflow is applied, which makes the situation underwater accessible to non-diving engineers for further planning. This interdisciplinary approach comprises also sound methods for technical surveys on dams (e. g. dam inspection or damage documentations).

Figure 2: Technical inspection by Scientific Divers. Especially the in-situ documentation is crucial as an objective risk assessment is not possible from the water surface.

3. TECHNICAL SURVEYS OF DAMS BY SCIENTIFIC DIVERS

Constructions of hydraulic engineering must be inspected in defined periods. Especially the parts of the construction underwater need a qualified inspection and documentation (Figure 2), as in most cases the responsible planner or engineer of the competent authority is not able to reach and thus inspect the location / damage by its own.

Therefore, the establishment of standardized-testing-procedures, as are already applied for the survey of bridge buildings and in structural engineering, are proposed for risk-assessments. In Germany's national standardization, these procedures are included in the DIN standard 1076 or RI-EBW-PRÜF. Applying these standards to underwater locations, a detailed evaluation of the technical state or damages can be derived (Figure 3).

The damage is evaluated according to the German directive RI-EBW-PRÜF (Figure 4), which is the fundamental guideline for standardized documentation and assessment of structural damages.

Each component is individually graded concerning the criteria stability, safety and durability. The evaluation of all single grades results in a main-grade for the whole construction. All grades range from 1.0 (very good condition) to 4.0 (insufficient condition). The summary of all documented issues provides a total grading on the condition of the building, which is an objective and comparable value for further procedures or decisions. Based on these grades, priorities can be set and operators may plan an investment or repair / mending more efficiently.

The structural investigations are a fundamental tool for planning maintenance and thus structural strengthening and renovation.

Besides these complex technical documentations, investigations of external impacts on the dam constructions are possible. For example, cracks, biofilms and consequent corrosion can be investigated by Scientific Divers (Figure 3) to apply optimized countermeasures for the respective location. Afterwards, specific preventing methods could be inferred to avoid or minimize future damages (e.g. antifouling).

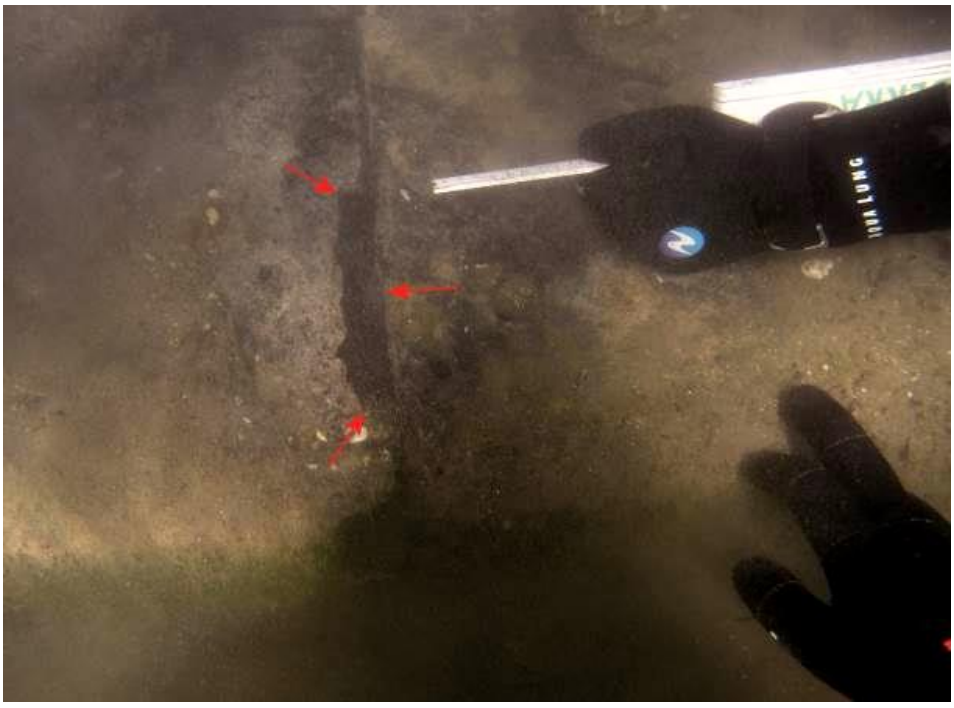

Figure 3: Complex cracks in a concrete wall. Detailed documentation is only possible in-situ and should be carried out by qualified engineers.

DEKRA

Type of damage including condition assessment

Damage-ID **398**

barrage
example barrage

construction
gate valve / bottom outlet

part of construction
rod

segment
console

material
steel

position / location
2. valve, 3. console

description of damage (short)
corroded

quantification of damage
medium

grading
after DIN 1076 / RI-EBW-PRÜF

stability	0
safety	1
durability	3

description of damage (long)
The rod console is heavily corroded. The rod itself moves stiffly within the socket.

calculated grading

2,6

index of substance

2,5

Figure 4. Fictive evaluation sheet of a risk assessment from an underwater damage including final grading after DIN standard 1076 and RI-EBW-PRÜF

4. CONCLUSION

From a legal point of view, construction authorities must ensure that their constructions do not pose any threat to the public. The risk of possible hazards can be easily minimized by frequent structural investigations in combination with a solid risk assessment, ensuring an early detection of defects.

The necessary investigation of submergent construction parts should be carried out by certified Scientific Divers and comprise a reproducible workflow and a high-quality documentation, which enables non-diving engineers to fully assess the situation underwater. To ensure these criteria, a special diving training is needed in combination with modern, safe and sufficient equipment. Naturally, the diving inspection engineer must have the occupational qualification in addition to the diving certification to carry out such safety relevant testing.

An integrated risk-assessment should combine damage detection at high altitudes and in-situ investigation of underwater locations and give an objective and comparable value for decision makers.

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