

REMTECH Esonda 16 Settembre 2026

*"La manutenzione delle infrastrutture idroelettriche:
esperienze e nuove frontiere tecnologiche"*

Interventi manutentivi subacquei

Francesco Fornari

ENEL GREEN POWER



Il technical committee M è uno dei 23 TC attivi in ICOLD ed è costituito da 26 membri e 11 coopted members espresso dai rispettivi comitati nazionali

I mandato (TOR) del comitato e, ove completato, i bollettini finali pubblicati sono:

TOR1: Bollettino 168 – Raccomandazioni per il funzionamento, la manutenzione e la riabilitazione delle dighe

TOR2: Preparare un bollettino su “Riabilitazione delle dighe mediante tecniche subacquee”

TOR3: Bollettino 178 – Funzionamento delle strutture idrauliche delle dighe

TOR4: Insieme ai Comitati E e S, preparare un Bollettino, su “Gestione delle acque per la riabilitazione delle dighe”

TOR5: Preparare un bollettino su “Lezioni dai progetti di riabilitazione delle dighe”



WORKSHOP ON DAM REHABILITATION TECHNIQUES

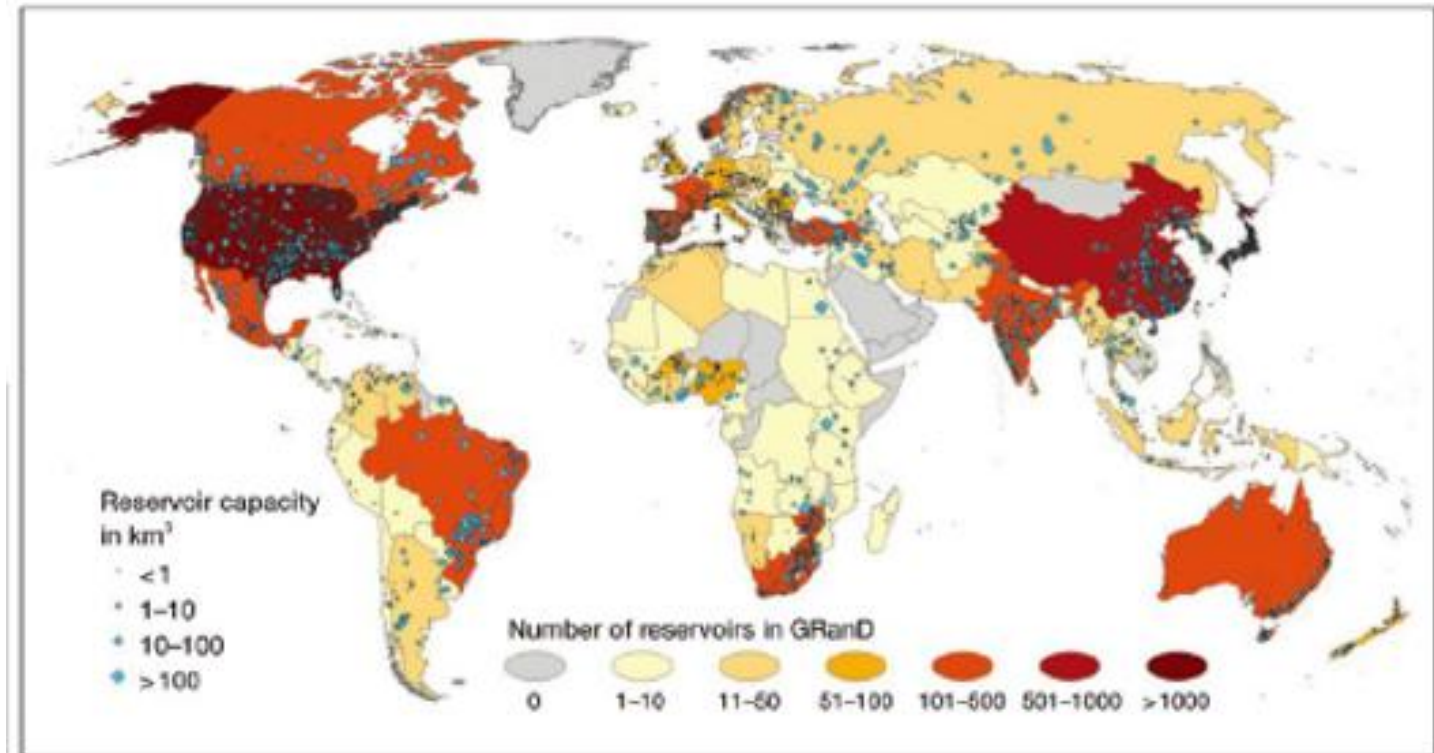
Considerazioni sulla diffusione ed età media dighe

*Research and Application of Dam Deep-Water Inspection and Repair Strengthening
Technology Equipment: From DeepSeek to DeepRepair Dr. Yan Xiang*



Asia, Europa e Nord America sono le aree più industrializzate anche dal punto di vista delle dighe

Country	Number
China	24 217
United States of America	10 053
India	4 489
Japan	3 178
Türkiye	1 923
Korea (Rep. of)	1 502
Canada	1 430
South Africa	1 409
Brazil	1 171
Mexico	1 106



Considerazioni sugli incidenti delle dighe a livello globale

High dam failures

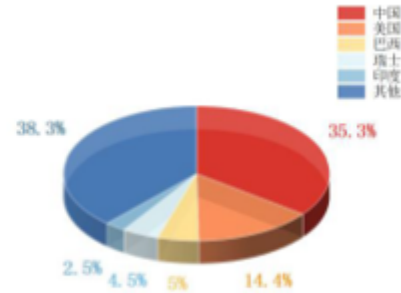
201

Involved countries

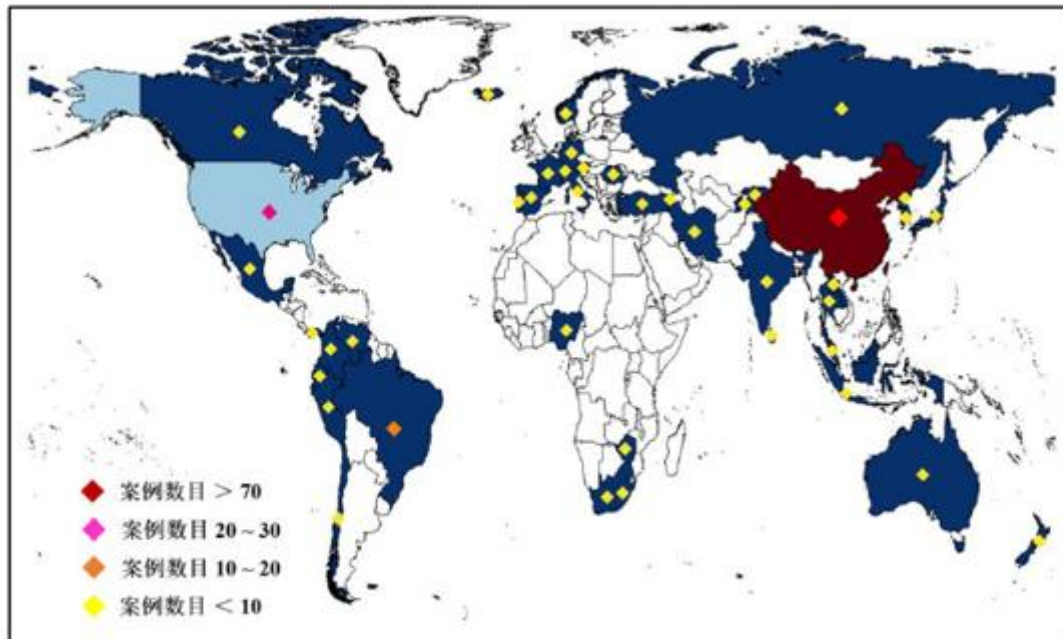
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Dam history (year)

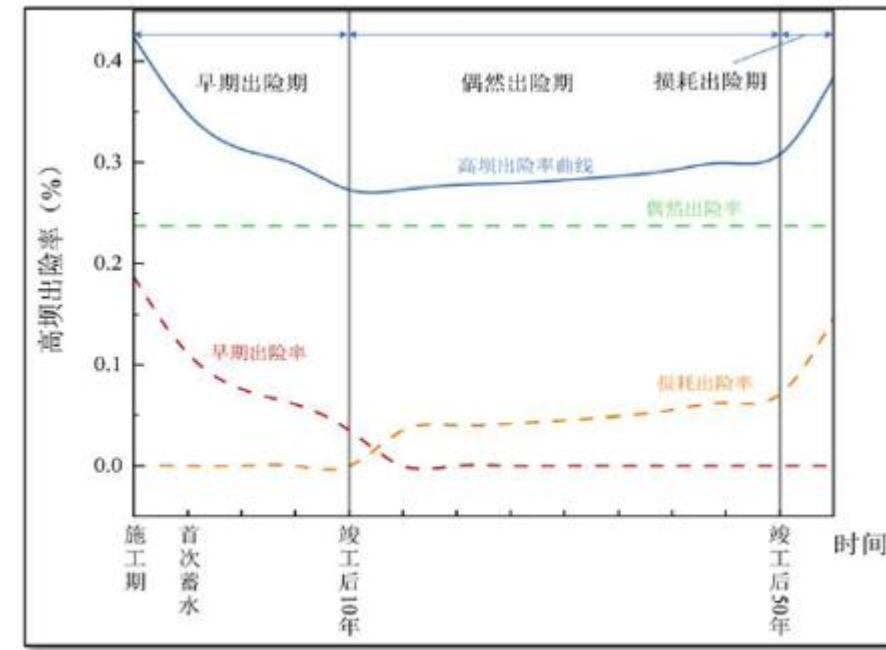
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La curva degli incidenti rilevanti registrata a livello globale da ICOLD evidenzia una fase di concentrazione rilevante durante I primi anni, una fase di maturita a tassi contenuti e una crescita al superamento di una soglia di invecchiamento



高坝出险案例国家分布 High dam failure map



高坝出险率浴盆曲线 High dam failure bathtub curve

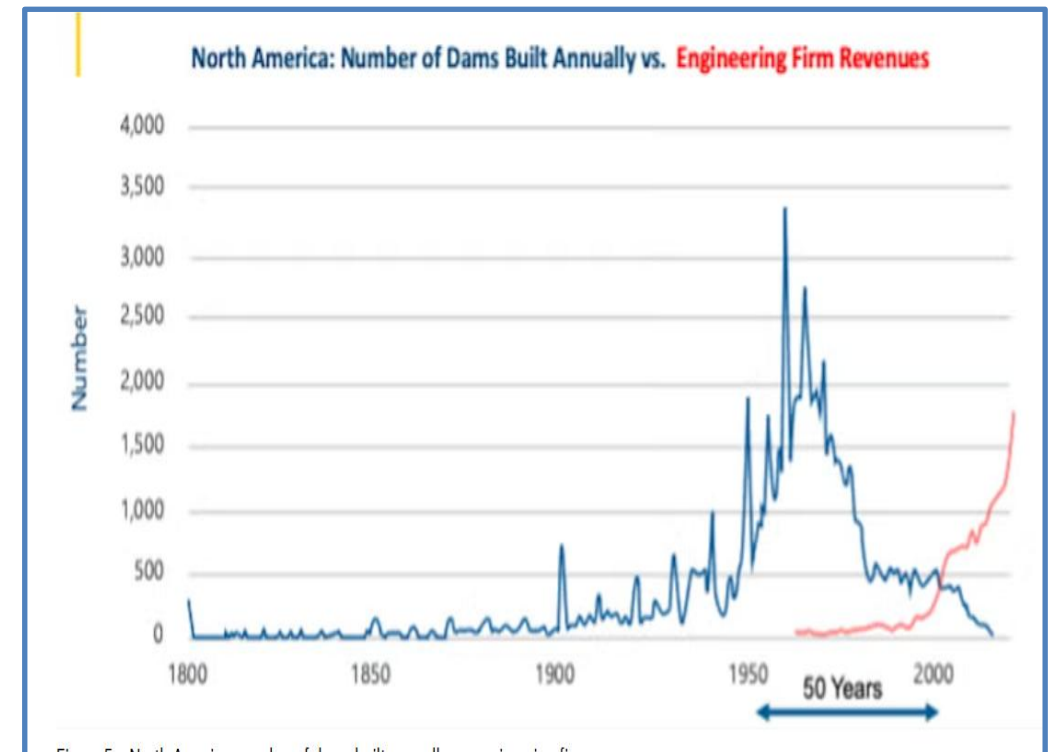
Crescita degli investimenti manutentivi

l'approvvigionamento idrico e l'irrigazione sono scopi primari per la costruzione di dighe, con circa il 70% dei prelievi globali di acqua dolce utilizzati per l'agricoltura

INTERNATIONAL
WATER POWER
AND DAM CONSTRUCTION

L'età media di una diga in tutto il mondo è di 60 anni. Il boom edilizio del secondo dopoguerra comportò ingenti investimenti in dighe e bacini idrici per sostenere la popolazione in rapida crescita. Negli Stati Uniti, il boom della costruzione di dighe raggiunse l'apice negli anni '80, quando iniziarono ad essere implementate leggi restrittive sulle autorizzazioni ambientali, e da allora è in costante calo

. A causa degli immensi costi e dell'impatto delle dighe, uniti alle difficoltà nelle approvazioni per questi progetti, l'uso dei bacini idrici esistenti viene sfruttato al massimo, ma questa estensione del ciclo di vita richiede una manutenzione e una riparazione significative e continue.



Crescita investimenti manutentivi in USA

Considerazioni sulle sfide connesse agli interventi senza svuotamento

Challenges

Repair and Reinforcement

Underwater/submerged operations at depths up to 60m

Drawdown

Extremely challenging or impractical to dewater, with prohibitively high costs

Sedimentation

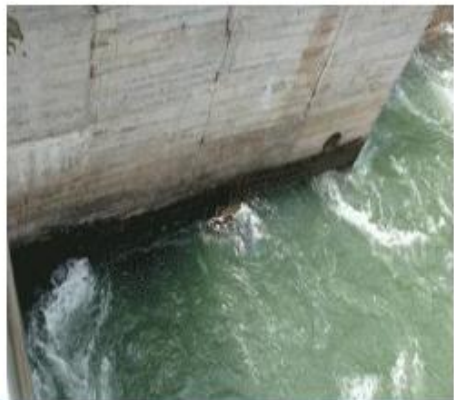
Unfavorable for underwater structure inspection, maintenance, and gate repair

Deep-water detection

Marine equipment is not adaptable to reservoir environments, and the introduction of relevant technologies faces restrictions, posing a bottleneck risk.

Diving

Depth limitations, low efficiency, high costs, and significant safety risks



Severe leakage



Face slab compression



Siltation of drainage facilities



Impractical to dewater

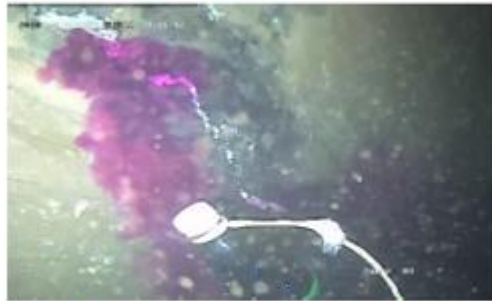


Rapid fluctuation of water level

Alcuni esempi di operazioni possibili



Crack measurement



Ink-tracing inspection



Crack cutting



Crack clearing



Grout preparation



Grouting



Grout pipe removal



Seal strip fixation



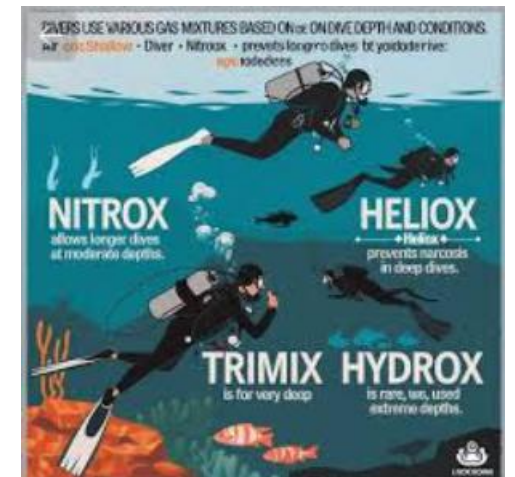
Leakage doublecheck

Nuove frontiere operative con operatore che può scendere sotto i 100 m

Achieve a major breakthrough in China's **deep-diving and inspection technologies** for reservoir dams, advancing from **60m to 120m**, providing cutting-edge technical support for the safe operation and management of high dams and large reservoirs, and filling a critical technological gap.



Helium-oxygen mixed gas diving at 100m depths



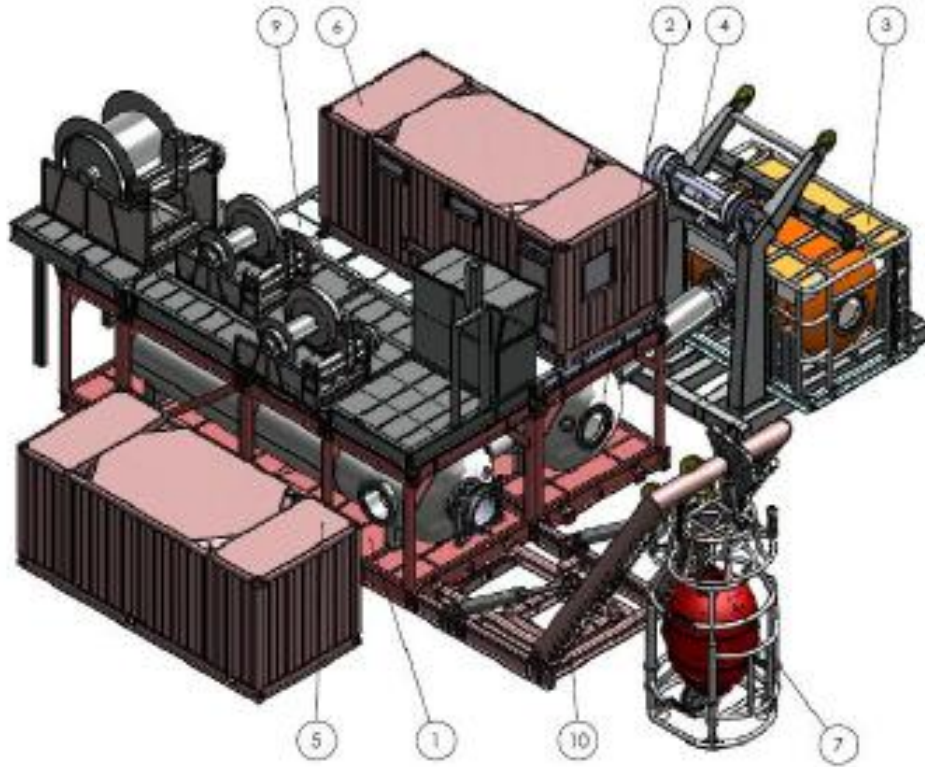
Una stazione operativa per effettuare tutte le attività senza personale a bordo



An automated equipment with modular, compact functionalities such as drilling, cutting, cleaning, and structural reinforcement is developed. This aims to achieve a breakthrough in deep-water inspection and operational technology for reservoir and dam systems, escalating from "1" to "N".

Deep-water inspection and operation platform

Una stazione operativa per effettuare tutte le attività con personale a bordo



When reinforcing large-scale damaged areas, divers are allowed to remain under high pressure for extended periods. Theoretically, **divers not constrained by underwater working time limitations** can effectively enhance the repair and reinforcement capabilities of reservoir and dam systems in deep-water environments.

Modular compact saturation diving system

Prima applicazione industriale

Impianto Guanyinyang 3000 MW



*The world's largest heliox mixed-gas diving engineering project &
the first large-scale application in China's hydropower industry*

Year: 2018-2019

Location: Guanyinyan Hydropower Station on the Mid-Reach of Jinsha River

Defect Description: Vertical and Horizontal Cracks spanning 6 dam sections with the total length of 290m

Equivalent diving depths: 59-127m.

1100_m

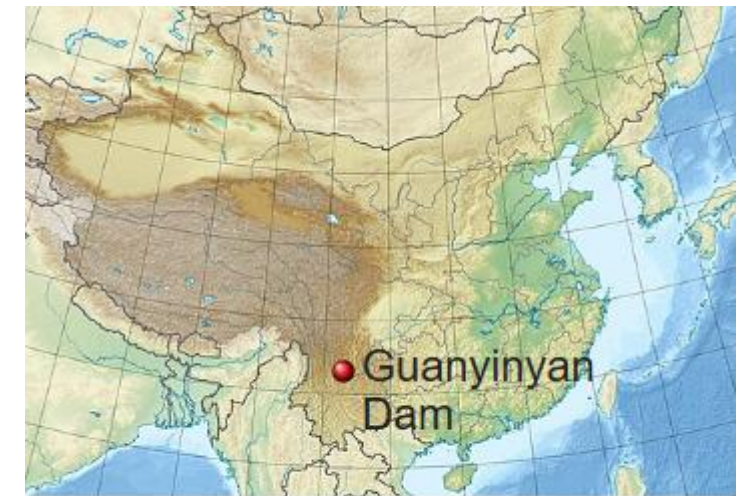
Altitude

>1000 shifts

Diving Shifts

59-127_m

Equivalent Depth



Location within China

Intervento di sostituzione di una catena a galle a oltre 100 m

More Heliox Mixed-Gas Diving Applications in Actual Engineering Cases



Huaneng Safety conducted a 110m depth emergency salvage operation for a 20+ ton chain wheel in the gate slot at a Dadu River hydropower station

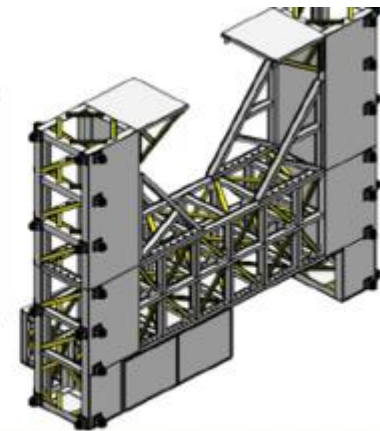
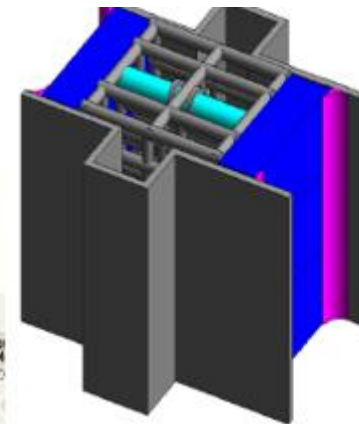
Flow Isolation Systems



青岛太平洋水下科技工程有限公司
Qingdao Pacific Diving & Technology Co., Ltd

To address the challenges where direct underwater repair by divers is unfeasible in long tunnels/high-velocity flow conditions and the low efficiency of large-scale underwater construction, our company has innovatively developed technical solutions including cofferdams, bulkhead gates, and other water-blocking systems.

Through coordinated installation by divers, **these solutions enable localized dewatered or zero-flow conditions at targeted construction zones**, thereby meeting the technical requirements for subsequent defect remediation works.



Intervento di riparazione urgente in una immissione in pressione

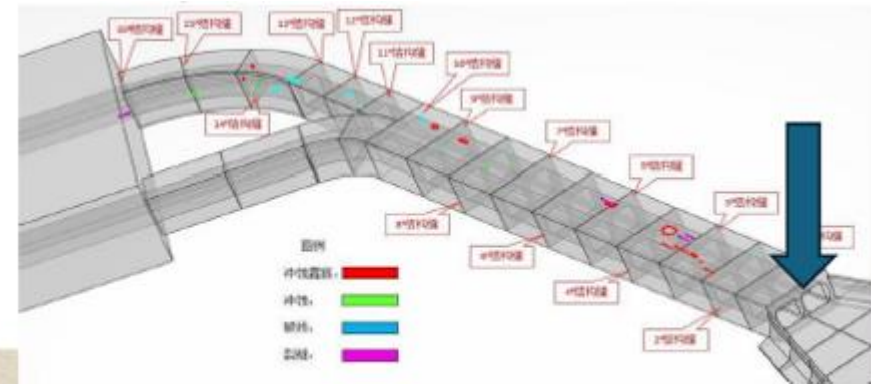
Case 4 - Defect Treatment Project of the Drainage Box Culvert



青岛太平洋水下科技工程有限公司
Qingdao Pacific Diving & Technology Co., Ltd.

Engineering problem: Through a comprehensive inspection of the drainage box culvert of one Ship Lock, it is found that there are more than a hundred defects, such as concrete damage cracks, erosion, and exposed reinforcement.

Engineering challenge: It is necessary to repair the concrete defects in the tunnel with a length of nearly 400 meters at a depth of 72 meters underground and a water depth of 17 meters. There are more than a hundred defects, and the construction period is only 15 days due to the impact of the shutdown.



Posizionamento teleguidato di un tamponamento provvisorio per messa in asciutta gallerie

Case 4 - Defect Treatment Project of the Drainage Box Culvert



青岛太平洋水下科技工程有限公司
Qingdao Pacific Diving & Technology Co., Ltd.

Technologies used: Underwater plugging technology of floating gate, and repair technology of concrete defects in wet environment on dry land.

Implementation effect: It has created the construction conditions of parallel operation on dry land at multiple working surfaces, successfully completed the repair work, and provided successful experience for the implementation of similar projects.



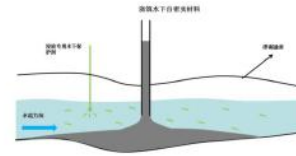
Un nuovo tipo di calcestruzzo per getti subacquei

*Engineering Application of Self-protected Underwater Concrete
Tsinghua Univ., China*

Prof. Feng Jin,

Demo of SPC

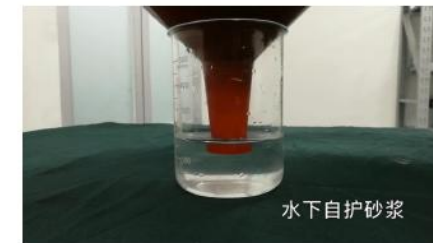
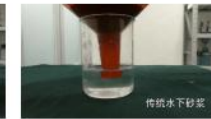
- Underwater Protective Agent (UPA) can protect cement particles in concrete from washing out



Ordinary mortar



Non-dispersive mortar



Self-Protected Underwater Concrete (SPUC) and Its Application



Prof. JIN, Feng
Tsinghua University
jinfeng@tsinghua.edu.cn
WhatsApp: +86 13501157293

Onsite test of SPUC



Lost ratio of cement < 0.5%;
Compressive strength at 28 d of
drilling core: 28.6MPa
meet design requirement

Test in lab for SPUC



Applicazione in vasca dissipazione senza prosciugamento

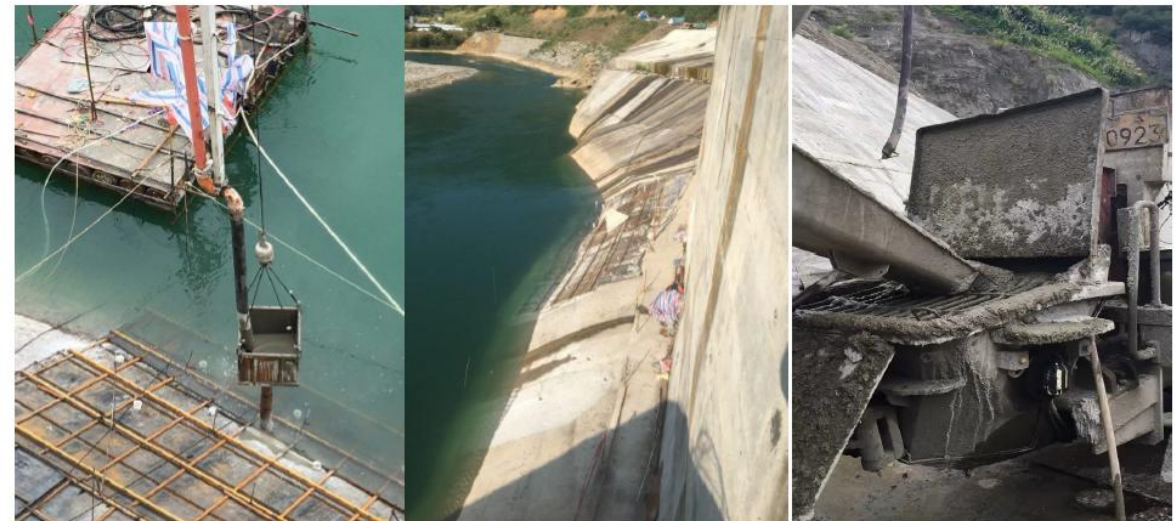
SPUC application: Longbeiwan

- The slope protection at the spillway downstream of Longbeiwan HPP was scoured during its first flood discharge in 2017
- Damage area span about 60 m long.



SPUC application: Longbeiwan

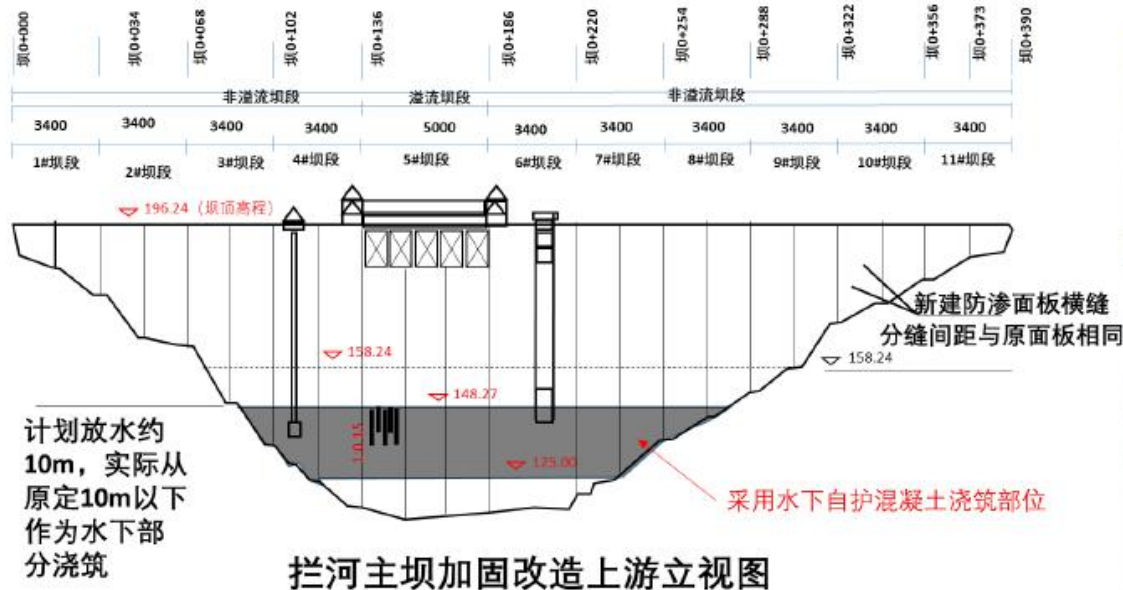
- SPUC was used to repair.
- About 880 m³ SPUC was casted in 75 h.



Applicazione su parte sommersa paramento di monte

SPUC application: Wanyao

- Wanyao is an RCC gravity dam with a height of 79.00 m
- The leakage along lift joints is severe.
- SPUC was used to cast an upstream impervious facing with a thickness of 0.5 to 0.8 m



Autonomous Casting System

Qingdao Pacific Diving & Technology Co.,Ltd

To enhance casting efficiency and reduce labor costs, our company has independently developed an Autonomous Underwater Concrete Casting System. This system features: Automated pour height sensing , Intelligent pipeline allocation , Precision slurry leakage detection .

Applicable to continuous underwater casting of mass concrete, ensuring homogeneity and pumpability under large-volume demands .



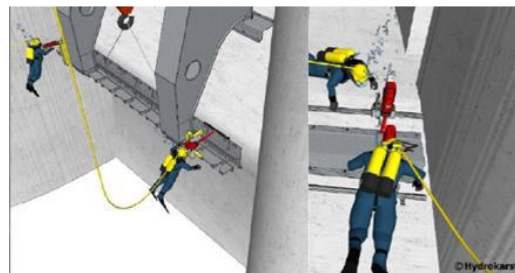
Bollettino ICOLD in preparazione

Rehabilitation of Dams Using Underwater Techniques Bulletin XXX

[COMMITTEE M - OPERATION, MAINTENANCE AND REHABILITATION OF DAMS]

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- CASE HISTORIES





乾杯/干杯

GAMBEI!