TECHNICAL REFERENCE

# Mosul Dam
## Rehabilitation Project

Governorate of Nineveh, Iraq

**Drilling & Grouting**

**Civil & Hydromechanical Works**

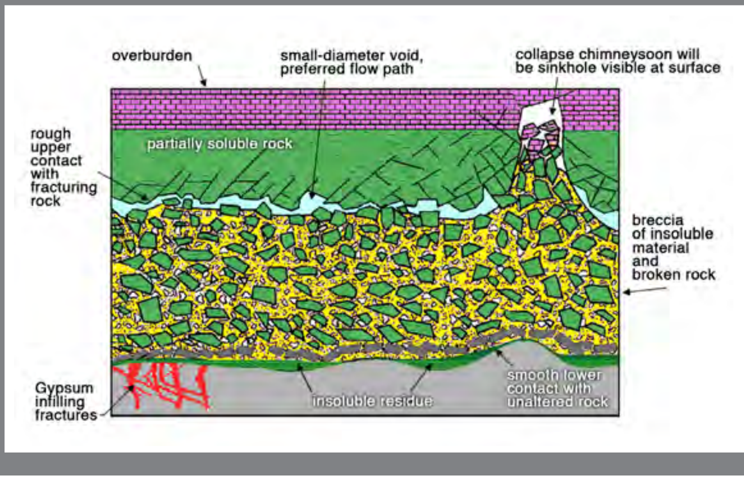
| | |
|---|---|
| Owner: | MINISTRY OF WATER RESOURCES OF IRAQ |
| Engineer : | **U.S. Army Corps of Engineers** |
| Main Contractor : | **Trevi S.p.A.** |
| Duration of works: | **02/03/2016 - 12/08/2019** |

## Introduction

Mosul Dam is an earth fill dam, located in Northern Iraq, on the Tigris River, approximately 40 km northwest of Mosul. The construction of the dam was completed in 1984. It is one of the largest multi-purpose dams in the Middle-East, and the largest Dam in Iraq.

The dam is a multi-purpose dam providing flood control, irrigation, power generation, and water supply. Through its 113 m height and 3.65 km length, the reservoir has a storage capacity of 11.1 billion m$^3$ of water. The main hydroelectric power station has 4 turbines for an installed capacity of 750MW. The discharge system foresees two bottom-outlet tunnels *(10 m in diameter)*, a five-gate service spillway, and an emergency fuse-plug spillway.

Typical outcrop with visible gypsum dissolution



## A problematic geological setting

The dam is founded on a layered sequence of rocks including marls, chalky limestone, gypsum, anhydrite, and limestone. A feature of the geology is the occurrence of karstic limestone and the development of solution cavities within the gypsum and anhydrite layers. Dissolution phenomena result in the formation of fissures and voids that allow considerable water percolation, due to the strong hydraulic gradient imposed by the Dam. The karst development extends to a depth of 100 m below the dam's foundation.

The under-seepage phenomena and the associated risks were identified during the design for the dam construction, and actions were taken in an attempt to mitigate the possible outcomes. To this aim, a deep grout curtain was designed to be installed all along the dam centerline, from a grouting gallery. The grouting gallery was constructed on top of the foundation rock, along the longitudinal axis of the Dam, before placing the embankment; the gallery was specifically designed also to allow repeated grouting efforts to continue over the lifetime of the dam.

The original specialized subcontractor initiated an aggressive grouting program in 1984, but the impoundment of the reservoir began whilst the curtain grouting was in progress. Afterward, the Iraqi Ministry of Water Resources (MoWR) has continued grouting ever since 1989, using the equipment and technique left at site by the subcontractor.

In spite of the actions taken, over the years the structural integrity of the dam and its operational capacity were cause for concerns, mainly because of the evident phenomena of dissolution of the gypsum and anhydrite layers. The rate of subsurface dissolution was increased by the presence of the reservoir; above a pool elevation of 318 m, the rate of subsurface dissolution increased markedly, leading to the recommendation that the pool not be raised above this level.

The low reservoir level impacted the power generation and the agricultural irrigation. In addition, the geopolitical instability in Northern Iraq almost interrupted the ordinary operations of maintenance grouting (managed by MOWR) between 2014 and 2015; and it is believed to have further impacted the condition of the Dam foundation.

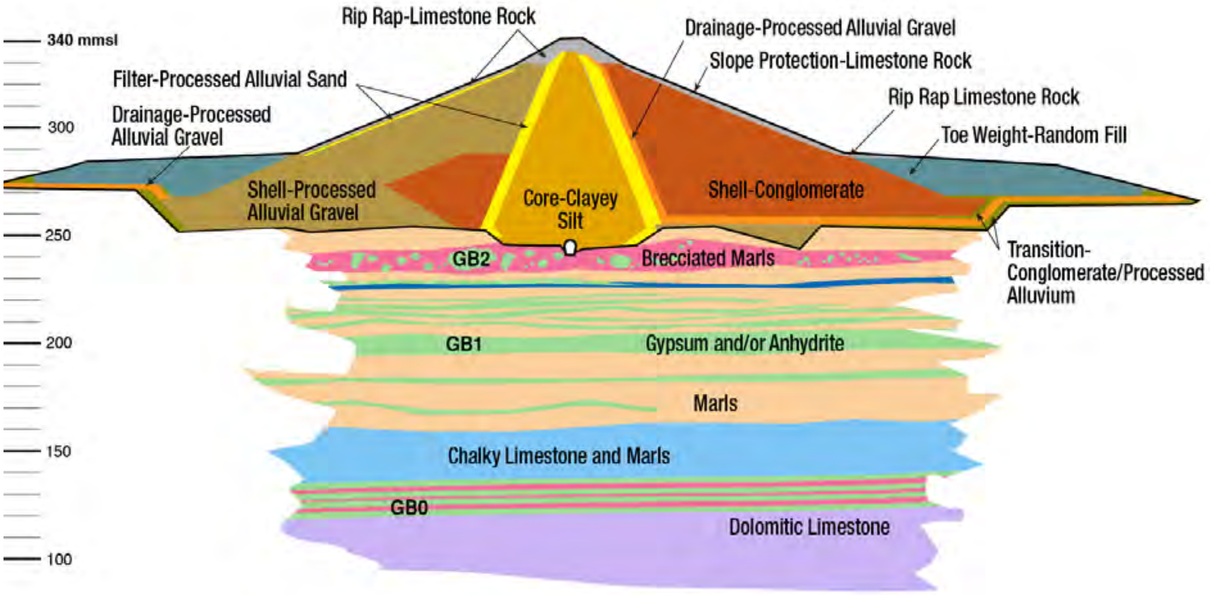
## The tender for the remedial works

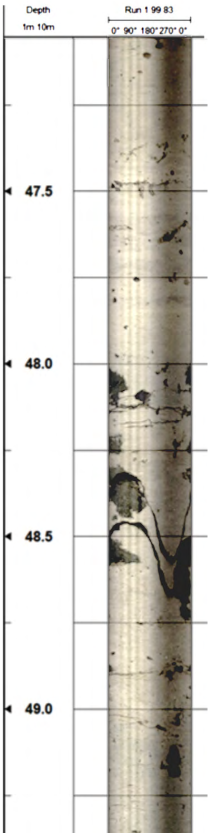
In **2016, the U.S. Army Corps of Engineers** (USACE) performed a risk-assessment analysis and identified various Potential Failure Modes at the highest risk level, all related to the risk of internal erosion through the foundation bedrock.

The risks for Mosul Dam were classified as very high, mainly due to the dam location and the number people living in along the Tigris Valley: if the risks were not addressed, failure can result in catastrophic loss of life, economic damage, and geopolitical instability.

Owing to the critical situation, **the Government of Iraq awarded the Mosul Dam Rehabilitation Project to the Italian firm Trevi S.p.A. (Trevi Group)**, through an international bid launched in October 2015. The Contract between the Iraqi Ministry of Water Resource (MoWR) and TREVI was signed in early March 2016. The Government assigned the roles of Engineer and Contract Administrator to the USACE, monitoring Mosul Dam since May 2015.

The contract included all the activities aimed at repairing the grout curtain, with the supply of all the equipment and materials necessary to execute the drilling and grouting intervention. The contract included as well the works for the repair and maintenance of structures associated with the bottom outlet tunnels.





## Camp and site preparation, and infrastructure upgrading

**Mobilization and site preparation faced logistic problems related to the site location, with the war conflict against ISIS at 13 km from the Dam.**

The setting up of the site began in July 2016, with the construction of a secure base camp facility to provide living and working accommodations for the approximately 1400 people on site. Also, it was started the installation of six new office buildings, of a new repair-maintenance shop, of the grout and mortar mixing plants. Concurrently, activities were started for the replacement of the entire grouting infrastructure and the construction of new networks for electric-power, ventilation, communication and internet, water and wastewater systems.

## Drilling and grouting works

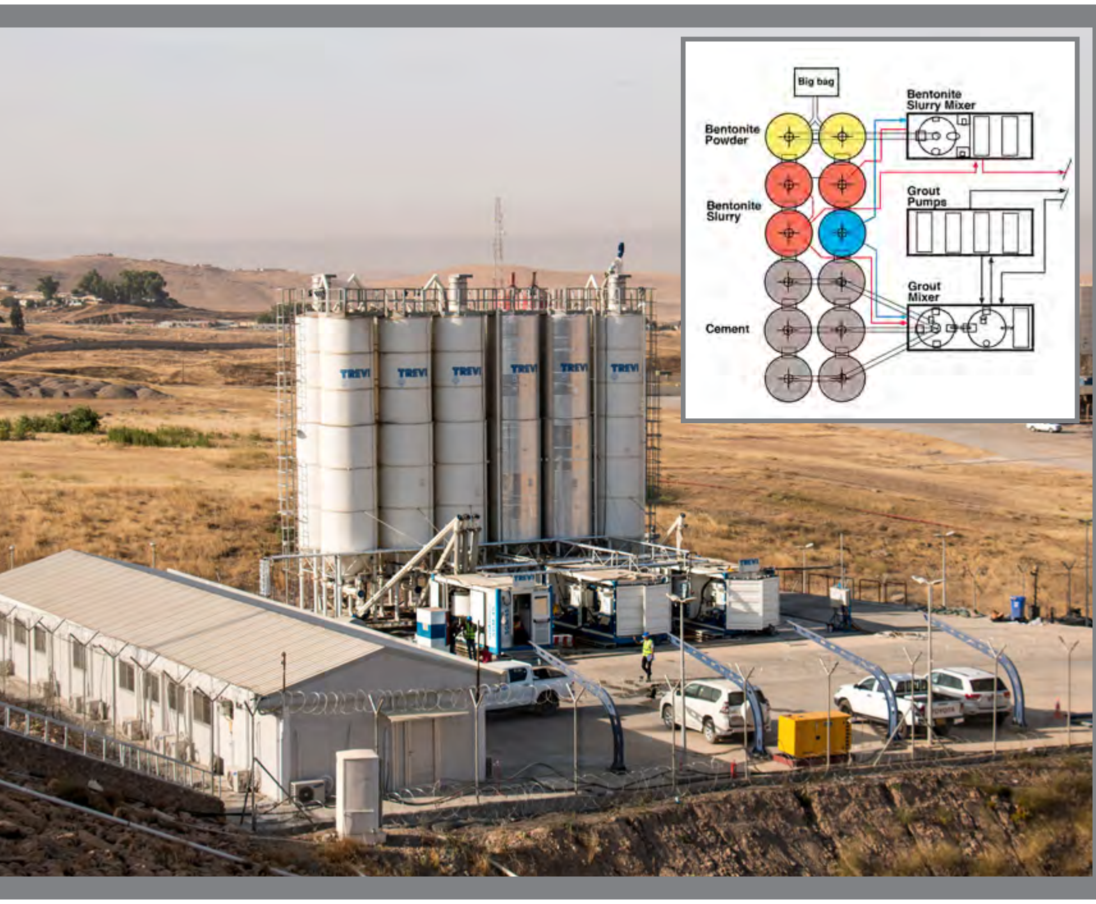
The drilling and grouting activity for the Dam refurbishment started at the end of October (2016). The drilling and grouting works were carried out with the goal of injecting mixes able to intercept and plug the fissures and voids (mainly derived from dissolution and karst phenomena). The end purpose of the emergency grouting program was to install a grout curtain along the full length of the grouting gallery (2200 m) and at the East and West Abutments (490 and 220 m). A further piece of curtain was installed from the crest of the Main Dam in the 280 m immediately right of the spillway, to grout the rock between the base of the embankment and the top of the grouting tunnel extrados *(where the grouting gallery enters the foundation rock).* Owing to the stratigraphy and design considerations, it was necessary to drill and inject holes to a depth of 150 m and over.

As a result of the water level in the reservoir, the gallery activities were further complicated by the need to operate in the presence of a significant water-head (up to 100 m).

### Drilling and Grouting Equipment

At the main dam, the injections were executed from the 2200 m long gallery, resting on top of the foundation rock, at the base of the impervious core. The gallery is accessible only through two long and small adits located at left and right banks. The features of the gallery *(3.7 m high and 3.0 m wide, with slopes up to 41%)* posed significant challenges in terms of equipment configuration and maneuvering requirements, entailing the use of small-size rigs and grouting plants. **SOILMEC supported TREVI in customizing the machines with special features.**

For the production and delivery of the base grout mix, TREVI deployed three Main Mixing Plants (MMPs), installed outdoor and strategically located to feed the new grout pipelines placed along the crest and the grouting gallery. Each automated mixing plant included a **Soilmec SGM-45** *(capable to produce 30 m$^3$/hr of grout)* equipped with twelve 45 m$^3$ silos *(for cement, water, dry and hydrated bentonite)* and four horizontal piston pumps (**Soilmec SGP-20.12**). The pumps SGP-20.12 delivered the fresh grout mixture from the MMPs to the grouting stations, while keeping it in circulation through a 20-Km long closed circuit split in 6 pipelines.



Twenty grouting stations were located in the gallery and on the dam crest, nearby the grouting points. Each station included an automated batching grouting unit *(BGU)* type Soilmec SGP-9.12M, equipped with a vertical piston pump and a dosing-dilution system, to prepare the design mixes as needed.

Six Soilmec SM-5E electric crawler-mounted rigs were supplied for the drilling works inside the gallery. Few months later, four additional rigs were provided *(SM-5EM)*. This new type of rig was custom designed to better fit within the limited space available in the gallery; also, allowed the drilling works under the spillway, where the gallery is characterized by a furtherly reduced section *(2 m wide, 3 m high)*. Seven diesel rigs *(SM-5 and SM-16)* were supplied for the outdoor drilling works. The three SM-16 *(long-mast rigs)* were equipped with a powerful double rotary, to allow the simultaneous driving of auger rods and steel casing for drilling the embankment.

All the rigs were equipped with a drilling parameter recording device *(DPR for penetration and rotation speed, thrust and torque pressure, fluid pressure, specific energy)*.

## Drilling and Grouting Method

According with the outcomes of the Risk Assessment Analysis *(USACE, 2016)*, the Dam's foundation was divided into "Critical Areas", which defined the grouting priorities.

At Mosul Dam, the grout curtain included three lines of holes. Each line comprised Primary, Secondary, Tertiary, Quaternary holes, split spaced, from 12 m to 1.5 m. Quinary holes were drilled in between, mainly for coring and verification purposes. Some additional boreholes were instructed, on the basis of the grouting and verification core results. Locally in the gallery, the grout curtain was integrated with an extra row of boreholes downstream inclined.

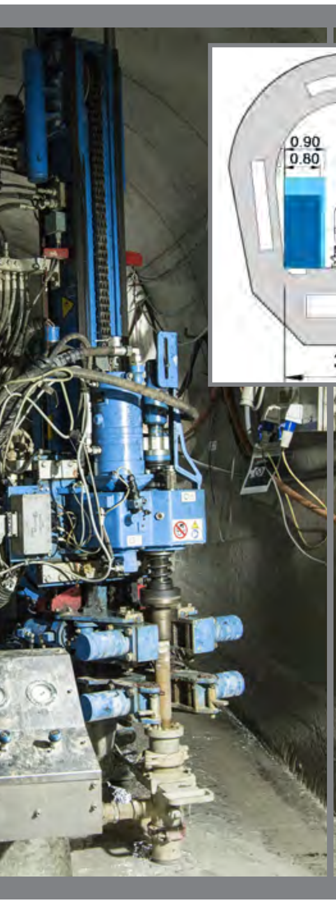
Almost all the boreholes were grouted to a depth ranging between 100 and 150 m depth.The holes bored from the crest of the dam involved the drilling of 10 to 40 m of embankment and core. The drilling through the embankment was performed by auger and temporary casing *(without any drilling fluid)* to prevent any possible hydraulic/pneumatic fracturing of embankment and clay core. A permanent plastic casing was cemented inside the borehole *(in the embankment and embedded 1 m into the rock beneath)* for the upcoming drilling and grouting of the foundation rock.

The drilling through the foundation rock was always performed by rotary system, using water as the flushing medium. Most of the drilled boreholes were vertical or subvertical. However, several boreholes were to be drilled in inclined array, to allow the continuity of the curtain under the seven water supply tunnels in the foundation beneath the grouting gallery *(the tunnels are related with the outlet structures, the power plant and a nearby pump storage facility).* Further inclined boreholes were drilled and grouted to connect the grout curtain installed from the East bank *(surface)* to the curtain installed under the concrete structure of the spillway.

The upstage method *(≤ 5 m long stages)*, was the most applied grouting method. The downstage and downstage-zone methods were also used, where needed by the borehole instability. For all cases, each borehole was pressure-grouted using a single packer, lowered in the hole at top of the stage to be grouted.

A series of stable grout mixes, characterized by different cement content, viscosity and setting time, were designed and tested. The aim was to have grouts able to treat both the large voids and the extensive net of fine fissures that characterize the foundation rock.

As a rule, the grouting of each stage was started with a thin grout *(both in density and viscosity)*, and continued with thicker grouts, with increasing cement content and setting fastener. The grouting volume for each type of mix was directed by a flowchart defining the relationship between the effective pressure recorded during grouting and the volume of mix being injected. The grouting pressure and methodology varied along the dam, based on encountered geology and observed issues while drilling. The maximum effective pressure to be used in each borehole at the different depths was determined on the basis of specific considerations, to get the best penetration while limiting the risk of rock hydro-fracturing. The completion criteria for each stage were based on the designed refusal pressure and flowrate, which had to be reached and maintained constant for a prefixed period of time. Once the closure condition was reached, a further waiting time was spent to allow the complete dissipation of the final back-pressure.



All the grouting operations were controlled, monitored and managed by “T-Grout”, a Trevi proprietary Automated Control System of the Grouting Process. The grouting software directly governs the whole grouting process and triggers mix changes based on pre-set criteria for pressures or volumes within the bounds of the refusal criteria. All the collected data are transmitted to the grouting software, which in turn regulates the pump pressure and flow-rate to maintain their values within the required limits. The software automatically computes the effective pressure, correcting the “raw value” measured at the borehole collar, taking into consideration all the dynamic and static head losses/gains. Wireless hotspots with internet connection were setup across the entire dam to enable communication among teams working simultaneously throughout the dam and the offices.

To this aim, the entire gallery and crest were equipped with a Local Area Network (LAN) using 2500 m of fiber-optic cable newly installed. With the help of the T-Grout system, more than 900,000,000 data were recorded and stored. This huge amount of data made possible the deep analyses of the

**403,115 m**

of grouted boreholes

man-hours worked without accidents

**8,000,000**

**40,833 m³**

of grouted mixes

**700 units**

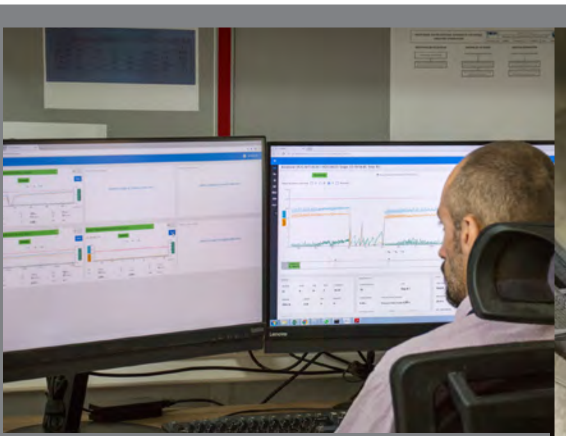
workforce

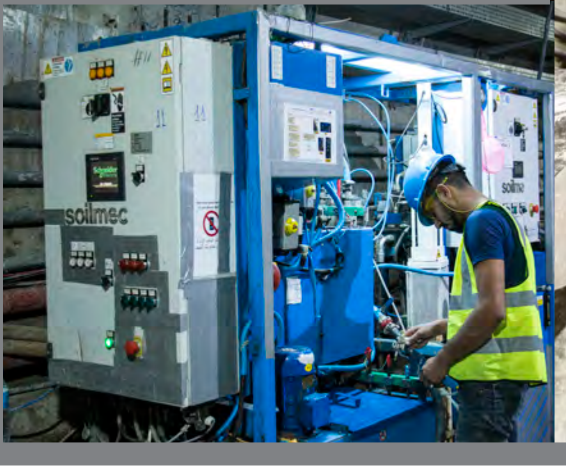
**5,393**

grouted boreholes

grouting behavior and foundation rock responses.
The drilling and grouting works included all the complementary activities, such as water pressure tests, coring, physical and electronic survey, etc.

Electronic equipment was extensively used to investigate the conditions of the rock, before and/or after grouting. The borehole optical televiewer (OPTV), capable of creating a high-resolution photographic image of the full circumference of the borehole, is a very useful instrument to provide reliable information on the state of the rock (and borehole deviation) in lieu of the time-consuming traditional coring. The use of the high-resolution acoustic televiewer (HRAT) allowed the surveying of boreholes in the presence of turbid water. The closed-circuit television camera (CCTV) was used to generate electronic high-resolution video of boreholes above the groundwater level. The high-resolution impeller flowmeter (HRIF) was used to measure the artesian flow rate encountered in the boreholes at various depths.





## Grouted quantities and results

The drilling and grouting works were performed 24 hours/day, six days/week. From November, 2016 through July, 2019, Trevi completed 403,100 m of grouted holes injecting over 40,800 m$^3$ of grout mixes, with an average grout take of 102 l/m. The activity involved 667,800 m of rotary drilling/redrilling, 85,000 m of coring, 35,450 m predrilling in the embankment.

The boreholes in the lower part of the gallery were drilled and grouted in challenging conditions, due to very high reservoir level. Here, the artesian pressure and water flow required significant efforts to complete the grout curtain and to install the upstream piezometers. As expected, the largest grout takes were recorded in the vuggy limestone and GB layers of the Lower Gallery.

In general, the downstream line *(the first injected)* recorded the highest grout takes. Within each line, the grout takes significantly decreased from the primary holes towards the secondary, tertiary and quaternary holes. The decreasing trend in terms of grout take is a clear signal of the void filling and gradual reducing of the residual permeability. In addition to the holes inspected by OPTV, check holes were cored-drilled and investigated by water pressure tests to evaluate the grouting efficacy. The 81% of the tested stages measured values LU ≤ 1 and the 98% LU ≤ 3. In general, the result of the Lugeon tests was evaluated as a great improvement.
Besides the drilling and grouting works, activities were performed to install and renew the inclinometer and piezometer array, both downstream of the dam and into the gallery.

These instruments allowed the monitoring of the hydraulic pressures in the dam foundation bedrock, and their behavior as the grouting activity progressed. The readings showed an evident amelioration of the hydraulic conditions, with noticeably increasing of the hydraulic gradient between upstream and downstream piezometers.

A new risk analysis downgraded the risk to a level significantly lower than the one evaluated in 2016. The general safe conditions of the Dam allowed for the water to rise again at levels of 2005 and for the reopening of the spillway.

## Rehabilitation of the bottom outlet tunnels

An important part of the contract was related to the rehabilitation of the Bottom Outlets. The first operation performed was the repair of the Guard Gate of the West Bottom Outlet, that was broken in closed position since 2013. Trevi managed to safely repair the indicator rod that was preventing the opening of the guard gate, restoring the full functionality of the guard gate system. The tunnel was reopened in October 2016, and water flowed through the west bottom outlet for the first time since 2013. The guard gates were inspected and found to be in good condition. New indicator rods were designed and installed at both the gates.

Trevi managed also the maintenance and repair of all the dewatering system of the tunnels, and of the four main gantry cranes located at the guard gate tower, at the bottom outlet regulating structure, at the spillway, and at the hydropower intakes.

Another remarkable feature was the inspection and maintenance of the steel bulkheads. The bulkheads are lodged in a concrete structure located into the lake at about 40 m depth. With the deployment of a dedicated pontoon and a specialized crew including 6 divers, the bulkheads were lifted to the surface and fully inspected. Inspection and refurbishment were successful, and bulkheads were returned to their storage position in the reservoir.

Having the bulkhead in place, it was possible the dewatering of the upstream culverts and the inspection of the whole length of the twin bottom outlet tunnels. These 700 m-long tunnels, are structures with 10 m diameter in the steel part and 12 m in the concrete section: all the joints and expansion joints were inspected and repaired where necessary.

A structure with dentates was designed and installed at the bottom outlets to dissipate the water energy during operation. Bathymetric surveys and hydraulic computer models were applied to evaluate the scour potential in the plunge pool. The outcomes were used to appraise methods for the plunge pool stabilization.

## Training of local staff

Under the Contract, Trevi had to train the local MoWR staff and technicians for the operation, maintenance and repair of the drilling and grouting equipment. It was an important issue, because the drilling and grouting works will have to be carried out through the entire life of the dam.

To engage the Owner's personnel to a learning process for the use and application of the modern equipment and techniques, TREVI held specific and exhaustive training courses for a total of 155 among engineers, technicians and operators. Theoretical classes and field activities were organized for the Iraqi personnel to familiarize with the new equipment, methodologies and technologies.

The USACE-Trevi team had further extended the training concept to include the integration of MoWR personnel into the Contractor's crews, with the aim of coaching the MoWR work force to directly execute the work on their own in the upcoming years, with the newly implemented techniques, equipment and software. Integration was achieved by establishing effective approaches for knowledge transfer to the

Environment | 2019-06-19

## Mosul Dam working at its best: minister

### Extensive training

### Dam is working well

Nuovo capitolo nella

**Sconto Nespresso**
Con Nespresso Easy ottieni credi
caffè. Scopri ora

banche creditrici".

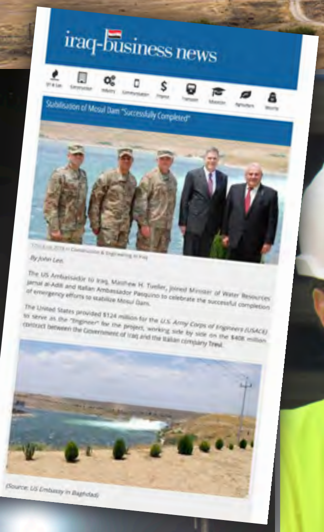
Secondo il board, le affermazi
manovra stessa e, con essa, la
distorsivi nel mercato" per cui i
e degli amministratori della soc

Il cda ha comunque avviato le a
chiedendo alla società informazi
luglio per l'adozione delle relativ

In quell'occasione, il board inten
consolidati, nonché proseguire ne
attualmente sottoposta agli organi
dell'assemblea dei soci sia per l'ap
quelli in scadenza.

Trevi a Piazza Affari tratta a 0,252

## Iraqi Ministry of Water Resources: Mosul Dam is safe



iraq-business news

### Stabilisation of Mosul Dam "Successfully Completed"

By John Lee.

The US Ambassador to Iraq, Matthew H. Tueller, joined Minister of Water Resources Jamal al-Adili and Italian Ambassador Pasquino to celebrate the successful completion of emergency efforts to stabilize Mosul Dam.

The United States provided $124 million for the U.S. Army Corps of Engineers (USACE) to serve as the "Engineer" for the project, working side by side on the $408 million contract between the Government of Iraq and the Italian company Trevi.

(Source: US Embassy in Baghdad)

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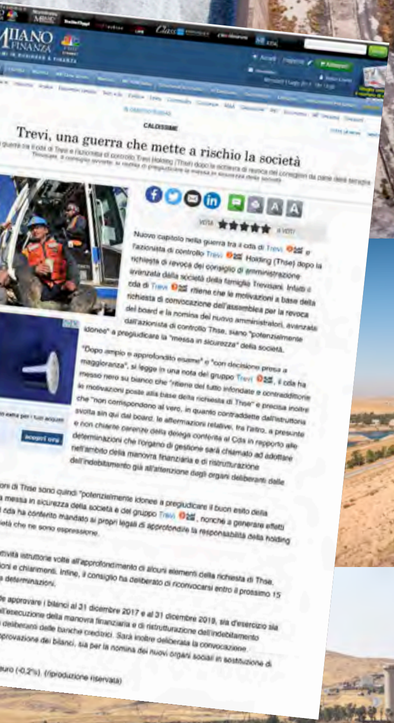
By TAD D



MILANO FINANZA

CALDISSIME

## Trevi, una guerra che mette a rischio la società

guerra tra il cda di Trevi e l'azionista di controllo Trevi Holding (Thse) dopo la richiesta di revoca del consiglio da parte della famiglia Trevisani, il consiglio avverte: si rischia di pregiudicare la messa in sicurezza della società

Nuovo capitolo nella guerra tra il cda di Trevi e l'azionista di controllo Trevi Holding (Thse) dopo la richiesta di revoca del consiglio di amministrazione avanzata dalla società della famiglia Trevisani. Infatti il cda di Trevi ritiene che le motivazioni a base della richiesta di convocazione dell'assemblea per la revoca del board e la nomina dei nuovi amministratori, avanzata dall'azionista di controllo Thse, siano "potenzialmente idonee" a pregiudicare la "messa in sicurezza" della società.

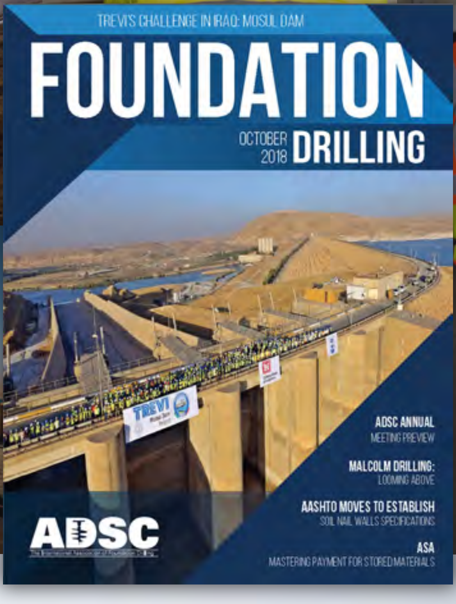
"Dopo ampio e approfondito esame" e "con decisione presa a maggioranza", si legge in una nota del gruppo Trevi, il cda ha messo nero su bianco che "ritiene del tutto infondate e contraddittorie le motivazioni poste alla base della richiesta di Thse" e precisa inoltre che "non corrispondono al vero, in quanto contraddette dall'istruttoria svolta sin qui dal board, le affermazioni relative, tra l'altro, a presunte e non chiarite carenze della delega conferita al Cda in rapporto alle determinazioni che l'organo di gestione sarà chiamato ad adottare nell'ambito della manovra finanziaria e di ristrutturazione dell'indebitamento già all'attenzione degli organi deliberanti delle

ori di Thse sono quindi "potenzialmente idonee a pregiudicare il buon esito della
a messa in sicurezza della società e del gruppo Trevi, nonché a generare effetti
l cda ha conferito mandato ai propri legali di approfondire la responsabilità della holding
ietà che ne sono espressione.

ttività istruttorie volte all'approfondimento di alcuni elementi della richiesta di Thse,
ioni e chiarimenti. Infine, il consiglio ha deliberato di riconvocarsi entro il prossimo 15
a determinazioni.

e approvare i bilanci al 31 dicembre 2017 e al 31 dicembre 2018, sia d'esercizio sia
all'esecuzione della manovra finanziaria e di ristrutturazione dell'indebitamento
i deliberanti delle banche creditrici. Sarà inoltre deliberata la convocazione
pprovazione dei bilanci, sia per la nomina dei nuovi organi sociali in sostituzione di

euro (-0,2%). (riproduzione riservata)



TREVI'S CHALLENGE IN IRAQ: MOSUL DAM

# FOUNDATION DRILLING

OCTOBER 2018

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MEETING PREVIEW

MALCOLM DRILLING:
LOOMING ABOVE

AASHTO MOVES TO ESTABLISH
SOIL NAIL WALLS SPECIFICATIONS

ASA
MASTERING PAYMENT FOR STORED MATERIALS

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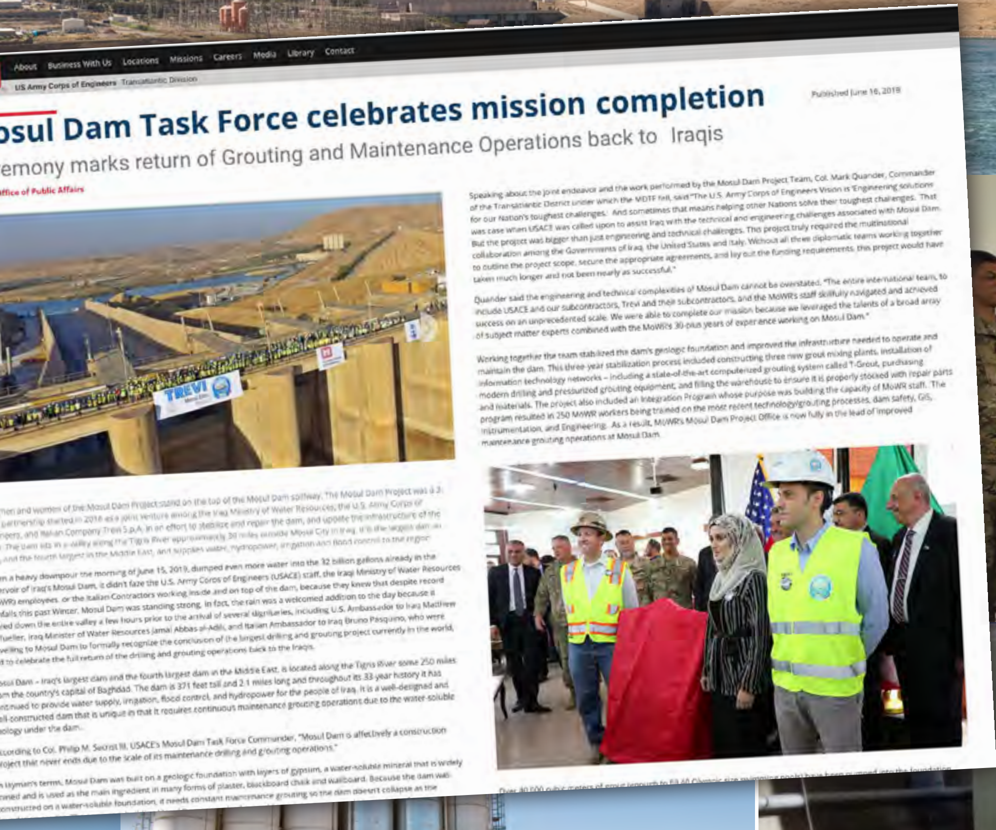

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US Army Corps of Engineers Transatlantic Division

Published June 16, 2019

## osul Dam Task Force celebrates mission completion

### emony marks return of Grouting and Maintenance Operations back to Iraqis

Office of Public Affairs

men and women of the Mosul Dam Project stand on the top of the Mosul Dam spillway. The Mosul Dam Project was a 3
partnership started in 2016 as a joint venture among the Iraq Ministry of Water Resources, the U.S. Army Corps of
ngers, and Italian Company Trevi S.p.A. in an effort to stabilize and repair the dam, and update the infrastructure of the
. The dam sits in a valley along the Tigris River approximately 30 miles outside Mosul City in Iraq. It is the largest dam in
, and the fourth largest in the Middle East, and supplies water, hydropower, irrigation and flood control to the region

m a heavy downpour the morning of June 15, 2019, dumped even more water into the 32 billion gallons already in the
ervoir of Iraq's Mosul Dam, it didn't faze the U.S. Army Corps of Engineers (USACE) staff, the Iraqi Ministry of Water Resources
WR) employees, or the Italian Contractors working inside and on top of the dam, because they knew that despite record
falls this past Winter, Mosul Dam was standing strong. In fact, the rain was a welcomed addition to the day because it
ved down the entire valley a few hours prior to the arrival of several dignitaries, including U.S. Ambassador to Iraq Matthew
Tueller, Iraq Minister of Water Resources Jamal Abbas al-Adili, and Italian Ambassador to Iraq Bruno Pasquino, who were
velling to Mosul Dam to formally recognize the conclusion of the largest drilling and grouting project currently in the world,
d to celebrate the full return of the drilling and grouting operations back to the Iraqis.

osul Dam – Iraq's largest dam and the fourth largest dam in the Middle East, is located along the Tigris River some 250 miles
om the country's capital of Baghdad. The dam is 371 feet tall and 2.1 miles long and throughout its 33 year history it has
ntinued to provide water supply, irrigation, flood control, and hydropower for the people of Iraq. It is a well-designed and
ell-constructed dam that is unique in that it requires continuous maintenance grouting operations due to the water-soluble
ology under the dam.

ccording to Col. Philip M. Secrist III, USACE's Mosul Dam Task Force Commander, "Mosul Dam is affectively a construction
roject that never ends due to the scale of its maintenance drilling and grouting operations."

n layman's terms, Mosul Dam was built on a geologic foundation with layers of gypsum, a water-soluble mineral that is widely
ned and is used as the main ingredient in many forms of plaster, blackboard chalk and wallboard. Because the dam was
onstructed on a water-soluble foundation, it needs constant maintenance grouting so the dam doesn't collapse as the

Speaking about the joint endeavor and the work performed by the Mosul Dam Project Team, Col. Mark Quander, Commander of the Transatlantic District under which the MDTF fell, said "The U.S. Army Corps of Engineers Vision is 'Engineering solutions for our Nation's toughest challenges.' And sometimes that means helping other Nations solve their toughest challenges. That was case when USACE was called upon to assist Iraq with the technical and engineering challenges associated with Mosul Dam. But the project was bigger than just engineering and technical challenges. This project truly required the multinational collaboration among the Governments of Iraq, the United States and Italy. Without all three diplomatic teams working together to outline the project scope, secure the appropriate agreements, and lay out the funding requirements, this project would have taken much longer and not been nearly as successful."

Quander said the engineering and technical complexities of Mosul Dam cannot be overstated. "The entire international team, to include USACE and our subcontractors, Trevi and their subcontractors, and the MoWR's staff skillfully navigated and achieved success on an unprecedented scale. We were able to complete our mission because we leveraged the talents of a broad array of subject matter experts combined with the MoWR's 30-plus years of experience working on Mosul Dam."

Working together the team stabilized the dam's geologic foundation and improved the infrastructure needed to operate and maintain the dam. This three-year stabilization process included constructing three new grout mixing plants, installation of information technology networks – including a state-of-the-art computerized grouting system called T-Grout, purchasing modern drilling and pressurized grouting equipment, and filling the warehouse to ensure it is properly stocked with repair parts and materials. The project also included an Integration Program whose purpose was building the capacity of MoWR staff. The program resulted in 250 MoWR workers being trained on the most recent technology/grouting processes, dam safety, GIS, instrumentation, and Engineering. As a result, MoWR's Mosul Dam Project Office is now fully in the lead of improved maintenance grouting operations at Mosul Dam.

Over 40,000 cubic meters of grout (enough to fill 40 Olympic-size swimming pools) have been pumped into the foundation

Iraqi staff, overcoming the language differences and bridging technical barriers.

## Conclusion

In the years, the workforce reached a pick of about 700 units, with Italian management and supervision, third-country national staff and local personnel.

Trevi commenced the works with the war conflict against ISIS at 13 km from the Dam. The presence of the Coalition Forces, together with the Italian Army, guaranteed the required security of the Project Area. Notwithstanding the strict security procedures, the works proceeded expeditiously with no delays till the end of the Contract *(July 2019).*

About 8-million man-hours were worked without recordable incidents.

TREVI
a TREVIGroup company

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