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COASTAL PROTECTION OF GOTVAND RESERVOIR DAM: ELECTRICAL CONDUCTIVITY PERFECTION OF SALTY DOMES

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The Gotvand reservoir dam is located at SW of Iran where the Karun River orients from the Zagros Mountains. The nominal volume is 5,500 million cubic meters. It is a rock-fills dam with clay core. The height of crown is about 180 m with 130 m normal water depth. Depth from bottom (0-30 m), the water layer's electrical conductivity (EC) will be as 150,000 to 85,000 mµ/cm. Also the EC will decrease from depth (85-30 m) corresponding the water layer's EC between 85,000 to 20,000 µm/cm. Finally, at depth (30-0.0 m) the EC is controlled with values (15,000-1,000 µm/cm). The salty domes will produce unexpected salty sediments into reservoirs. Consulting engineering said that more than 8,000,000 tons of pure salt sediments were interned into the Gotvand Lake reservoir from 2011 through 2015. If this regime of salty material continues, downstream agricultural lands will completely disturb and disuses. Turk salty concrete (SC) could present innovative solution to reduce salty feed in lake. It is based on the chemical reaction of salt-clay-cement that salty volumes could be stabled through special material injection inside the domes. Sliding resistance will be increased by SC injection in the salty dome layers. Finally, the salty sediment should be stabled by SC injection in the old mine Anbal salt dome. SC may be designed to cementize salty domes through powder of bentonite clay, type-II cement, water, and Shushtar ceramic clay.

Keywords: Karun River, Grouting, Bentonite, Ceramic clay, Anbal, Salty concrete.

1 INTRODUCTION

Small regular dams were designed by the American consulting engineering that will suggest in the Gotvand station with maximum height 30 m at 1974. Main target can be the electrical power plant. Also warning were declared to the ministry of power that the Karun River at the Gotvand axes will contact with the dangerous layers of Gypsum, Marl, Calcite, Salty domes and Gachsaran formations. Although the restrictions were warned to stop the construction dams in the Gotvand station, government is forced to start the construction through the powerful contractor at 2003. Executive revised design is submitted to the ministry of power to construct by the Iran Water Resource Management (IWRM). The Anbal salt dome demonstrates the great mistakes of Dam construction engineering. Figures 1 to 3 will be interpreted to occupy the huge salty man made mines. The total volume of salty dome will calculate approximately 700,000 tons that it will be presented by Eq. (1) and the EC profile in Table 1. It is mentioned that the intake tunnel of power plant is +159.0 m, agricultural tunnel (lower gate) at +123.0 m. Drainage glass reinforced plastic (GRP) pipeline gate will be fixed at +85.0 m for extreme salty sedimentary. Based on the reports, daily solvent can be computed by Eq. (2) that will be 1,200 (tons/day).

$$W(Anbal) = \tfrac{1}{3} Ah\gamma = \tfrac{1}{3}\left(16{,}500\,(m^2)\cdot 100\,(m)\right)\times 1.3\,(tons/m^3) = 700{,}000\ tons \tag{1}$$

$$\rho_{daily} = \frac{(\Delta W)_{tons}}{T_{day}} = \frac{\left(6.25_{(May\,2015)} - 5.25_{(Dec\,2012)}\right)\times 10^6\,(tons)}{28.7(month)\times 30(days)} = 1{,}200\ (\tfrac{tons}{day}) \tag{2}$$

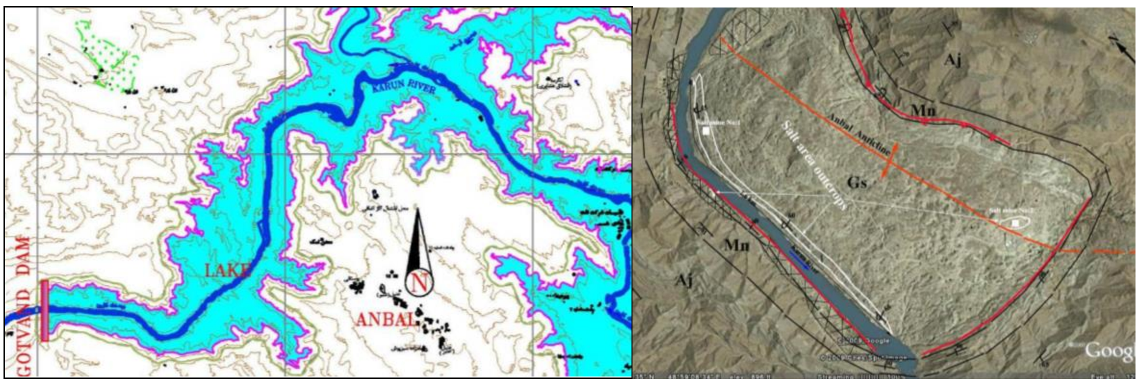

Figure 1. The Gachsaran formation and Anbal (or Anbar) anticline in plan (KWPA 2015).

Table 1. Demonstration profile of EC (μm/s) in the reservoir (KWPA 2015).

Column	Depth (m)	Level (m)	EC (May 2013)	EC (May 2014)	EC (May 2015)
Upper	0-35	195-160	470-600	520-600	383-600
Mid	35-70	160-125	1,000-10,000	900-10,500	950-10,300
Lower	70-110	125-85	10,000-110,000	10,000-108,000	10,000-109,000

The parameter *WANBAL* is referred to the total weight of Anbal Salty Dome, which may be computed through the conic volume, and DEM (digital elevation model). Based on the reports of Mahab-Ghodss consulting engineering, periods of days represent in Eq. (2) to calculate the rate of solvent salt weight per day (ρdaily). Salty materials sediment has been interned into the reservoir that will be very low resistance formations. Every day, interning the huge amount of salty combination solvent in the lake increases water density. Main salt material came from Anbal dome mines. Many shames are presented to the ministry of power by private and state organizations that all of them were scrutinized using the Tehran University in early years. Presented suggestions designs are listed as bypass tunneling, evaporation basin pot, and pipeline transferring into the Persian Gulf coast and diverting the main Karun River in the Gotvand station. Mortar mixture can use in the masonry or desired proposes in construction facility. It is mentioned that Both Salt and cement cannot be a chemical reactions in the mortar mixture. In this research, main parameters could be improved to adequate for injection propose in the salty domes through the SC that will contains the Shushtar ceramic clay, Bentonite clay, type II cement, pure ionize salt and fresh water. Specific properties will modify such as adherence, hardness, holding and plasticity index. Soil and concrete laboratory are providing the accurate tests. Innovate instrument may be used to inject the mixed grouting (Turk *et al*. 2008) by submerging parts and elastic pipes that will fall from the barges into the lake waterbed (KWPA 2015).

2 EAGLE TOE SIMULATION

Eagle toe simulation will improve the layer shear resistance. It is made by the submerge object to fall through barges into the lake water with steel screen pipe pin. Figures 2 to 3 and Table 2 will present the specifications of tripods injection grouting with screened pipes (Puller 2003). Grouting material will be injected into the undersea salty domes to improve stability (Turk and Zaemeri 2004).

2.1 Properties of Eagle Toe and Flexible Pipes

Schematic direction of eagle toe (ET) and flexible pipes (FP) presents in Table 2, Figures 3 and Figure 4 (Turk *et al*. 2007) that are made by high strength concrete and polyethylene silky strings pipes. All ET should be penetrated in the salty layers permanently. Eq. (3) to Eq. (9) will describe the model submerging behavior. In Table 2, the v_0 is the maximum velocity before the impact (items 1, 2). Total length of L_0 (item 1) is measured inside the salty dome penetration. Parameter T_0 is the time of model that will stop in the layer. In Figure 3, part D is referred to nailing of ET on the salty dome executions.

Table 2. Properties of ET and FP can demonstrate by nominal specifications (Turk 2001, Turk and Zaemeri 2004).

I	Item	Weight (tons)	Dimensions (cm)	Materials	Stress (kg/cm^2)
1	Screen pipe	0.20	20×500	Steel pipe	Fy = 2,400
2	Micro piles	0.05	7.5×500	Cement-clay-Bentonite	f'c ≥ 30.0
	Elliptic	2.10	3(100×200×20)	High strength Concrete	f'c ≥ 400
	Cylinder	0.35	1(50×150)	High strength Concrete	f'c ≥ 400
3	Flexible Pipe	3 (kg/m)	12.5 (diameter)	Polyethylene silky	Fy = 1,000

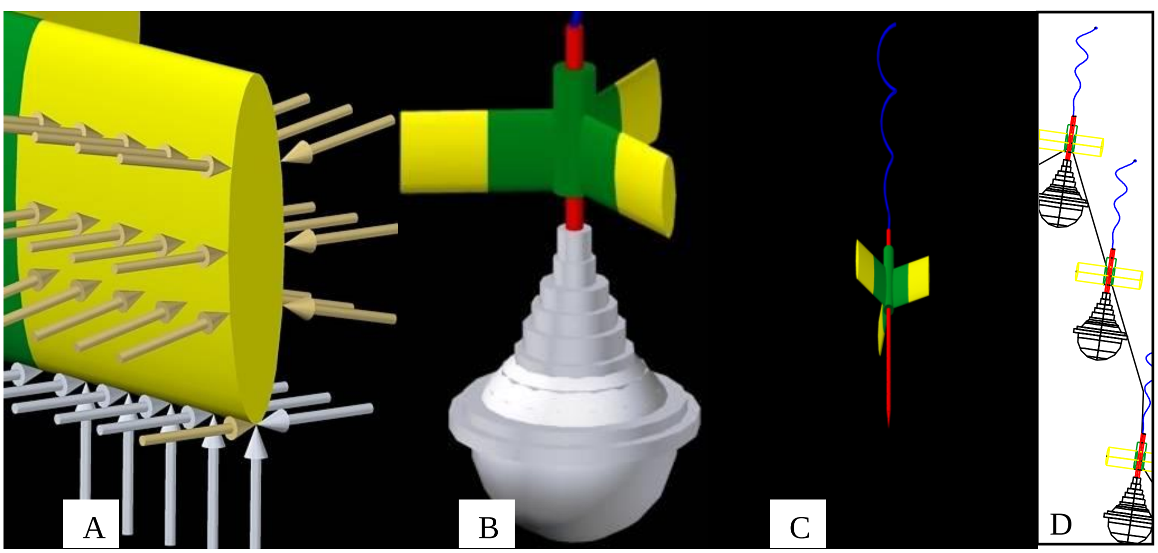

Figure 3. A: Stress vector form; B: grout injection; C: eagle toe schematics; D: nailing (Turk *et al*. 2008).

Table 3. Values of $L_\circ(v_\circ, T_\circ)$ for $f(v_\circ/T_\circ)_{(v_\circ=10, T_\circ=1)} = 10$, or $f(v_\circ/T_\circ)_{(20,\,3/4)} = 26$ (Turk *et al*. 2007).

T_0 (s)	V_0 =5(m/s), L_0 (m)	$v_\circ / T_\circ$	V_0 =10(m/s), L_0 (m)	$v_\circ / T_\circ$	V_0 =20(m/s), L_0 (m)	(V_0 / T_0)
1/2	1.3	10	20	20	5.0	40
3/4	1.9	6.7	3.7	13	7.5	26
1	2.5	5	5.0	10	10	20
3/2	3.5	1.6	6.5	3.1	15	13

$$M(v_\circ - v_1) = Ma_\circ(T_\circ - T_1) \Rightarrow \quad v_\circ = g\left(1 - \rho_{Water}/\rho_{Model}\right)t \tag{3}$$

$$L_\circ = \int_{x_\circ=0}^{x_\circ=L_\circ} dx = \int_{t=0}^{t=T_\circ} (v_\circ - \underbrace{a}_{cte.}.t).dt = \int_{t=0}^{t=T_\circ} (v_\circ - \underbrace{\left(v_\circ/T_\circ\right)}_{a_\circ}.t)dt = 1/2\, v_\circ\, T_\circ \tag{4}$$

$$\sum Fy = F_{TURK} = F_{impact} - (\sigma.A)_{soil} - F_{bouancy} \quad \rangle\, 1/3\, F_{bouancy}\,(N) \tag{5}$$

$$F_{impact} = \frac{m.\Delta v}{\Delta t} = \frac{m.\left(-g\left(1 - \rho_w/\rho_m\right)t\right)}{T_\circ - t} = \frac{m.v_\circ}{T_\circ} = 2'700\ f\left(v_\circ/T_\circ\right) \quad (N) \tag{6}$$

$$F_{Turk} = M_{Model}.\frac{g}{T_\circ}\left(1 - \rho_{Water}/\rho_{Model}\right).t - (\sigma.A)_{soil} - \tfrac{4}{3}V_{Model}.\rho_w \tag{7}$$

$$F_{Turk} = \underbrace{2'700\ f\left(v_\circ/T_\circ\right)}_{impact\ force} - \underbrace{\left(1\left(\tfrac{N}{cm^2}\right)\times 3\times 200\times 20\ (cm^2)\right)}_{soil\ stress} - \underbrace{11'000\ (N)}_{bouancy force} - 5'000N \tag{8}$$

$$F_{Turk} = \underbrace{2'700\times 12}_{impact\ force} - \underbrace{(12'000N)}_{soil\ stress} + \underbrace{15'000N}_{bouancy force} + \underbrace{5'000N}_{safty}) = 400 \geq 0 \tag{9}$$

3 TURK SALTY CONCRETE (TSC)

Tentative samples are made in the laboratory soil and concrete. The first sample is shown that the salt and cement cannot mix together to produce hardening materials. Sever exposure is a topic condition in the dam lake. Next mixture is designed to find new grouting material using the bentonite clay. This mixture shows the rising resistance of sample. But, it was very poor against the saturation condition and it will be changed to plastic behavior with no rigidity. New material is added to study the strengthen behavior by Shushtar ceramic clay that is referred in Figure 4 as clay material. The results will show the incredible rising of the compressive test. This processing is continued to find the best mix design, and saturation resistance. Variable percentages are mixed to determine the exact mixture design by the ionic salt, bentonite and ceramic clay, cement and water. Therefore new coefficient ζ_{Turk} is defined to compare the variable salty result tests. Figures 4 to 6 will describe the SC and additives clays. Compressive test will modify by ζ_{Turk} that will balance with Eq. (10) to Eq. (11). Also, sample S713 is the resistance index with 26-day break test. All 10 days σ_i samples over the $\sigma_{713,26}$ will produce the modify σ_i.

$$\zeta_{Turk} = (W_{Salt} + W_{Water}) / (W_{Cement} + W_{Bentonite} + W_{Clay}) \tag{10}$$

$$\sigma_{SC} = \sigma_{Test}\times\zeta_{Turk} \Rightarrow \left(\sigma_{10/713,26}\right)_i = (\sigma_{10})_i / (\sigma_{26})_{713} \times (\zeta_{Turk})_i \quad , i = 1,2,3,\ldots \tag{11}$$

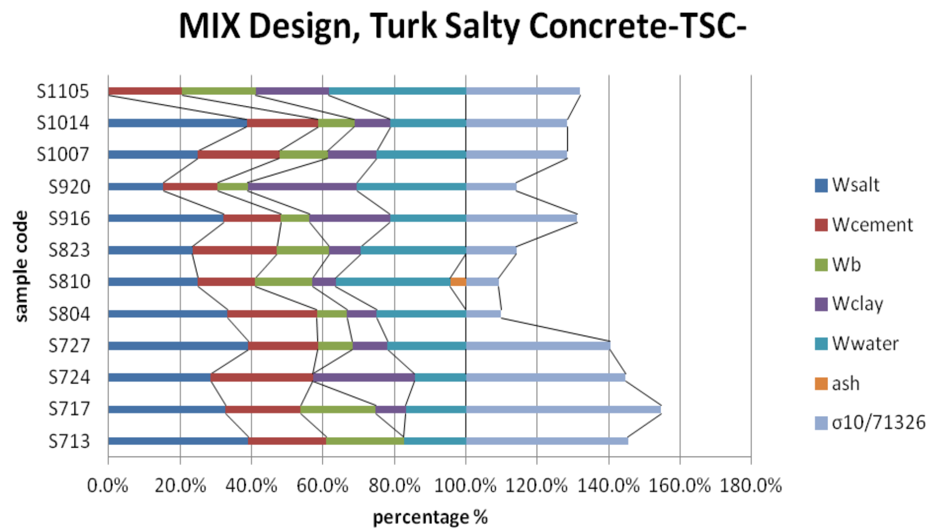

Figure 4. TSC mixture designs with wide range of the salty water; σ10/71326 refers to S713 at 26 days.

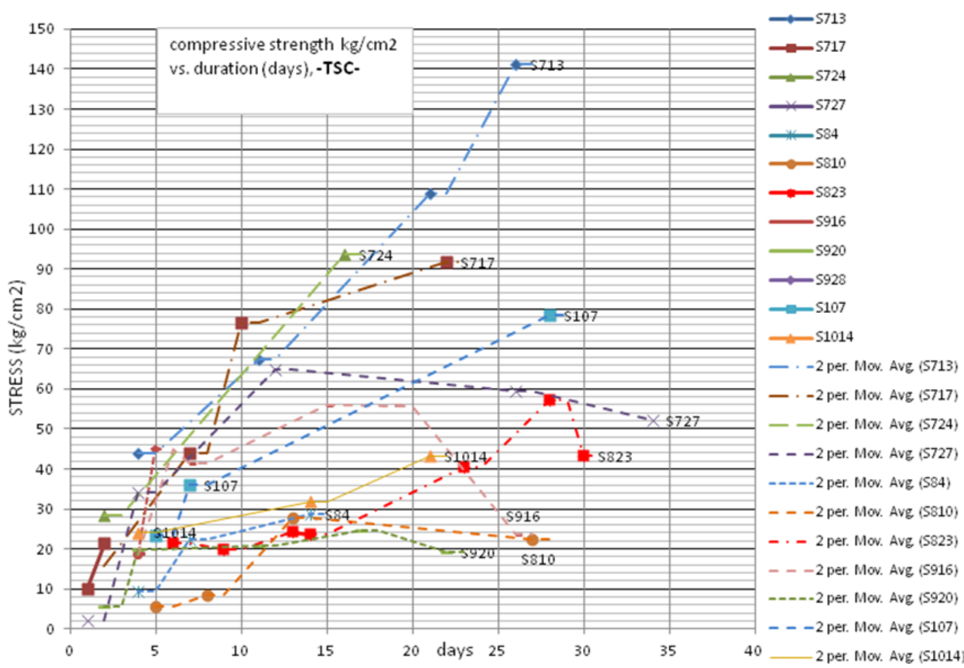

Figure 5. TSC compressive strength shows the 2 days through 35 days test results (KTNSE 2017).

4 EVAPORATION PONDS

Massive amount of high saline water is needed to remove from bottom of reservoir immediately. They finally mentioned although the evaporation pond in comparison to mechanical system is reliable and viable in terms of financial, environmental and technical aspects. The high-saturated brine is conveyed through GRP pipeline from the bottom of Gotvand reservoir to a series of evaporation ponds in which exceeding water is evaporated and salt is deposited.

Figure 6. The Persian Gulf water evaporates to obtain dry materials in the petrochemical basins.

5 CONCLUSION

Turk salt concrete will be the last solution to stabilize the salt domes. Also, eagle toe nailing will be a strong instrument to making the seal TSC curtain. Innovations grouting can be a halophytes material that may adsorb the salt of sediments. Laboratory Phase I, is finished by the selected mixture design. Next Phase II will be the exact dam formation material. Sampling will start before April 2017 in the Gotvand station. It is mentioned that nailing should be designed to construct arc curtain form inside the salt dome. It is referred to the arc stability and sliding resistance. The Phase III will discuss on the nailing components and directions. At the end of scenario, water level could be decreased to destroy the main body of the Gotvand reservoir dam in 5 years. In the meantime evaporation pond may build to collect the salty sedimentary. Nailing scheme will start at the coastal boundary and continue into the depth coast.

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