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ECONOMICAL STABILIZATION BASED ON TURK SALTY MORTAR AND GROUTING PROBABILITY FUNCTION IN SALTY FORMATIONS

AFSHIN TURK[1], BAHRAM MOMBENI[2], and SHABNAM GHANAVATIZADEH[3]

[1]*Dept of Dam –Developing and Utilization, Ministry of Power, KWPA, Ahwaz, Iran*
[2]*Dept of Water Supply, Ministry of Power, KWPA, Ahwaz, Iran*
[3]*Dept of Biology, PNU University, East of Tehran, Iran*

GOTVAND reservoir dam is located in the Karun River, SW of Iran. Dam Lake's coastline is covered by the salty ridges 500,000,000 tons with 5000 m coastlines length. Layers are combined by Salt, Gypsum, clay, Marl, Silt and dolomite. TSM- Turk Salty Mortar was invented in order to stabilize the salty ridges. Components of TSM are salty water, clay, bentonite and cement. Proportion (% of total by mass) is 65% salty water, and 35% other materials. It is estimated that salty materials inter the lake by 1300 tons per day. Grouting Cost determines more than 1,000,000,000 USD in 2017 that the government was declared previously. TSM is contended to finish the work less than 100,000,000 USD (90% discount). Another suggested layout is based on the diverting the Karun River path. This research is fixed to stabilize salty domes in place. TSM grouting inside the layers needs to draw an accurate plan. Random variable interaction is defined through the salty layer and TSM. Also, it is recommended to use the -TGDF- Turk Grouting Distribution Functions for technical grouting and effective economical radius. ΔP is the economical boreholes result that can be used to extend the length of grouting without cost. TGDF recommends the injection in salty layers only.

Keywords: Gotvand, Karun river, Salty domes, Cost and boreholes.

1 INTRODUCTION

GOTVAND reservoir dam was studied to submit the government by Consulting Engineering (HARZA 1968) that may build the step generator dam series with low crown height. Low crown level was replaced by the new government suggestion at 1980. Finally, the power politics were forced to archive the beneficial and safe design in the caisson. It is mentioned that Karun River is located in the Fertile Crescent (Britannica 2018). Dam ageing may take more valuable cost and time. River Diverting idea can be refused by geology weakness constrains and unsymmetrical settlements. Therefore, financials aids cannot support the modification project by limited time. Stabilization is the only and unique way that may modify the GOTVAND problems in the restrict time and water resource. It is tried to explain the modification methods by injection operations inside the salty ridges based on the mass probability functions and random variables theories. Main data are obtained by limited mixtures designs of TSM in the laboratory and geological boreholes. A set of data was modeled to recognize TGDF through the statistical and probability functions (Ross 2010). Basic density function is indexed by the laboratory test outcome same as the salt percentages, ζ_{Turk}, θ_{Turk} of samples. It was taken two years to obtain a suitable mixture designs which are made by experimental axial and Tri- axial pressure tests.

2 SALTY RIDGES FORMATIONS

Thickness and formations are registered in the field test by the geotechnical Boreholes in the GOTVAND Dam Lake. Figure 1. demonstrates the salty ridges in the Lake coastline. These salty domes may be stable with TSM in the range of ζ_{Turk} more than 0.50 and less than 3.00 ratios. Therefore, it is a limitation that need a relative criterion. Pure salty ridge was injected by the TSM grouting in order to stabilize the formations. In Eq. (2), the maximum effective θ is near the proportion $\theta=3/4$ of total weight. Probability mass function is produced by integration of Eq. (5) density function (Ross 2010) and limitations in Eq. (4).

Figure 1. Pure salty domes in coastline of GOTVAND Dam Lake (Turk *et al.* 2017, 2018).

3 TURK GROUTING DISTRIBUTION FUNCTION- TGDF-

Eq. (1) is referred to proportion by mass of salty water. Eq. (3) to Eq. (4) show the density function (Ross 2010) and boundary conditions. Eq. (5) explain the TGDF that can be produced by density function. This set of all possible outcomes of random variable *x* is known as the sample space of the experiment and is denoted by S in Eq. (4).

$$\zeta_{Turk} = \frac{W_{SaltWater}}{W_{Clay} + W_{Bentonite} + W_{Cement}} \tag{1}$$

$$\theta = \frac{\zeta_{Turk}}{\zeta_{Turk} + 1} \tag{2}$$

$$P\{a \le X \le b\} = \int_a^b f(x)\,dx, \quad F_X(x) = P(X \le x) \tag{3}$$

$$0.25 \le S(\zeta_{Turk}) \le 3.00 \Rightarrow 0.20 \le S(\theta) \le 0.75 \tag{4}$$

$$P_{Turk}(x)_j = \mu \underbrace{\sum_{j=1,i=1}^{j=7,i=14} \left(\frac{l_i \theta_i}{L = 150m}\right)_j}_{4.19} = 1 \Rightarrow \underbrace{\mu = 0.24}_{Table4} \tag{5}$$

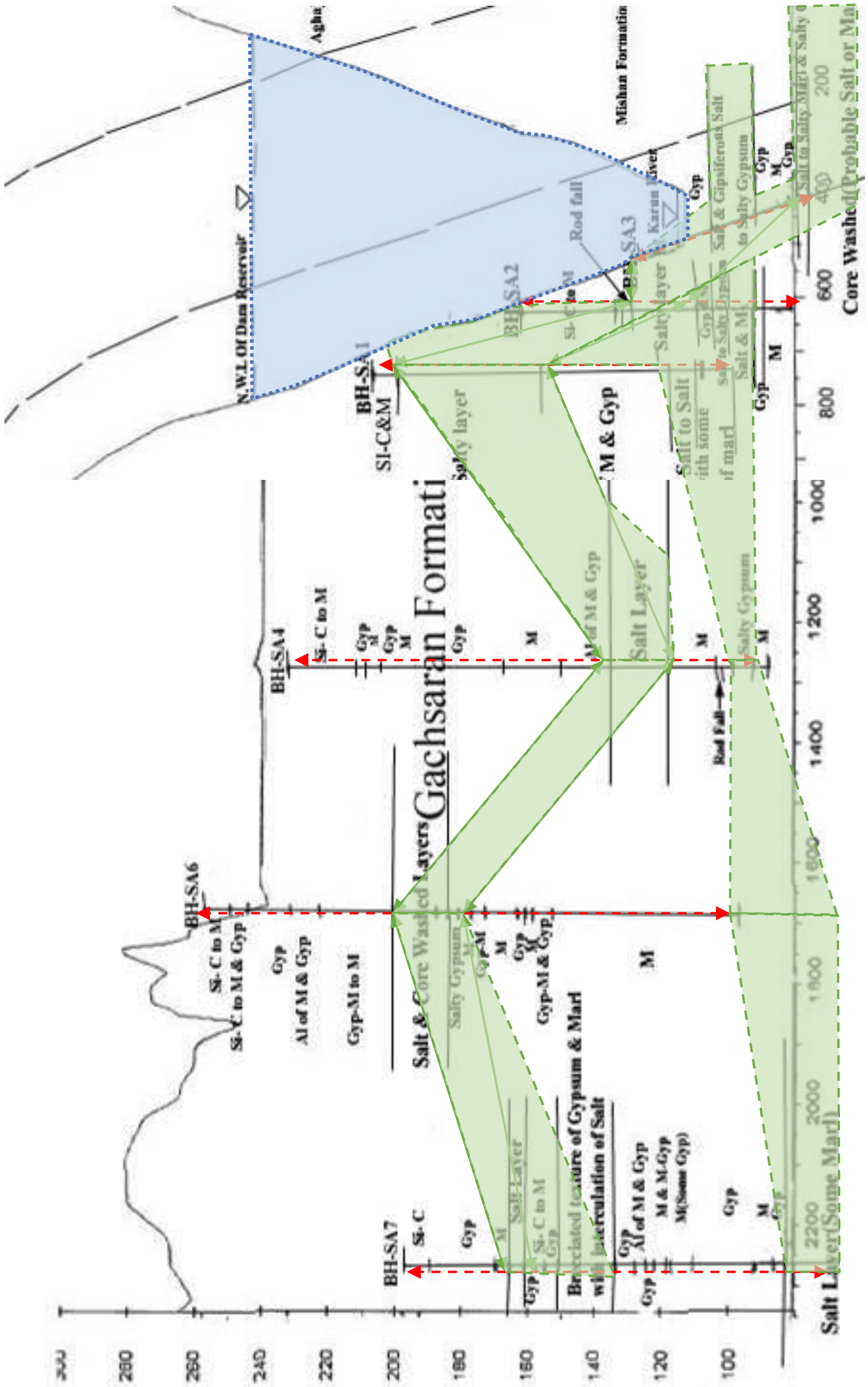

Figure 2. Exploration boreholes: BH-SA1, BR-SA2, BH-SA3, BR-SA4, BH-SA6 and BH-SA7.

Exploration boreholes are demonstrated by Figure (2) that salty layers are marked using the green transparent area in the Ambal Anticline. Table 1. shows the materials of boreholes such as salt, marl, gypsum, clay, silt and combinations of them. Eq. (6) is based on the ratio of $l_{si}\theta_{si}/L$ in each borehole. $P(x)_j$ determines the probability of successful injection that can interprets the independent random variable. Therefore, the $P(x)_j$ indicates in each boreholes of Table 1. (red text). Eq. (5) is modified to compute the independent values by Eq. (6) that is marked in Table 1. The values Δp in Table 1. are referred to economic aspects that will be achieved by the grouting in salty layers only. It is meaning that 174% positive benefits can be decreased the total cost. When the TGDF is computed in the whole length of boreholes then the successful probability decrees to 50% in BH-1. Comparison is demonstrated in Figure 3. with economical aspect.

$$P_{Turk}(x)_j=\sum_{i=1}^{i=14}\frac{l_i\theta_i}{L} \Rightarrow P_{Turk}(BH)_1=0.63; P_{Turk}(BH)_2=0.50 \qquad (6)$$

Table 1. Exploration boreholes in the Ambal Anticline salty ridges (Damough and Zarei 2011).

Samples	Marl	Gyp	Gyp, M	**Salt**	**Salt, Gyp**	**Salt, M**	Si, C, M	L(m)	$\frac{L_{Salt}}{L}$	$\frac{\theta_i \cdot l_i}{L}$	$\frac{\theta_{Si} \cdot l_{Si}}{L_S}$	+ΔP %
BH-SA1			30	80	15	15	10	150	73%			
θ_i	-	-	0.20	0.65	0.55	0.60	0.13			**50%**	**63%**	**23%**
BH-SA2	10	10	-	10	20	45	55	150	50%			
θ_i	0.20	0.20	-	0.65	0.55	0.45	0.13			**35%**	**50%**	**15%**
BH-SA3	10	10	10	25	60	35	-	150	80%			
θ_i	0.20	0.20	0.20	0.65	0.55	0.45	-			**50%**	**55%**	**5%**
BH-SA4	30	5	50	25		15	25	150	27%			
θ_i	0.20	0.20	0.20	0.65	-	0.45	0.13			**30%**	**56%**	**26%**
BH-SA5	25	55	-	35	-	-	35	150	23%			
θ_i	0.20	0.20	-	0.65	-	-	0.13			**30%**	**65%**	**35%**
BH-SA6	60	15	25	35	-	-	15	150	23%			
θ_i	0.20	0.20	0.20	0.65	-	-	0.13			**30%**	**65%**	**35%**
BH-SA7	15	15	45	15	30	20	10	150	43%			
θ_i	0.20	0.20	0.20	0.65	0.55	0.45	0.13			**35%**	**65%**	**30%**

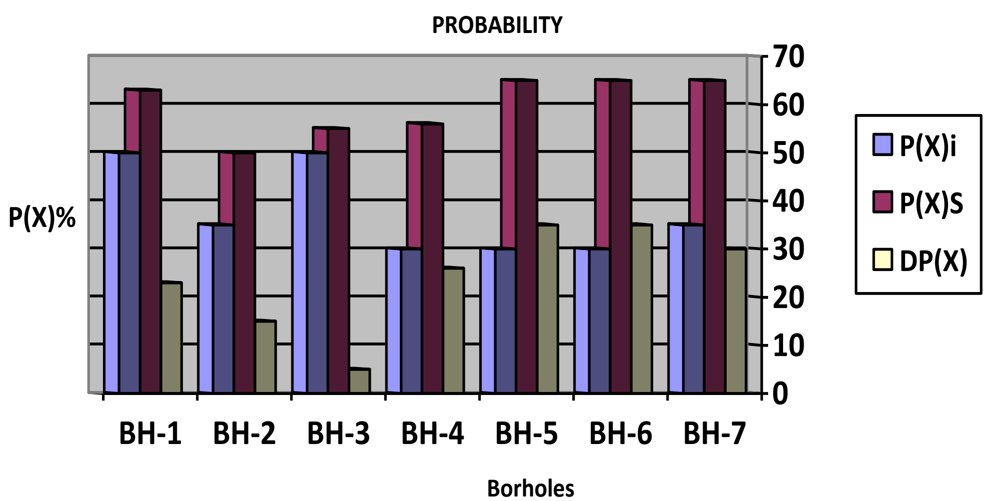

Figure 3. P(x)i refer to the whole layers of BH and P(x)s denoted the salty layers only.

4 STEP CONSOLIDATION OF TGDF

In Eq. (8) Step Consolidation S_C (Turk *et al.* 2018) is applied in the grouting phase to improve TSM resistance in the boreholes. Eq. (7) refer to the shrinkage (Beer *et al.* 2012) and the porosity n. ΔV over the void volume obtains the $(S_C)_{Turk}$ = 1.2 to 1.9 in pressure grouting stages (KTNSE 2018). Final Turk probability distribution function set as Eq. (9) that contains -Sc- Step Consolidation.

$$\eta_i = \frac{\Delta V_i}{V_\circ}, \quad n_i = \frac{V_{vi}}{V_{\circ i}} \tag{7}$$

$$(S_C)_{Turk} = \sum_{i=1}^{k} (\Delta V / V_v)_i \leq 1 \tag{8}$$

$$P_{Turk}(x)_{ji} = (S_c)_{Turk} \cdot \sum_{j,i=1}^{j=7,i=14} \left(\frac{l_{Si}\theta_{Si}}{L} \right)_j \tag{9}$$

4.1 Economical Grouting by S_C and ΔP%

TGDF for Table 1. are amount 0.50 to 0.65 in independent conditions with mean 60% ratio. This probability means 60% successfully grouting stabilization. ΔP in Table 1. is mentioned that grouting should be executed only in the pure salty layers and combination of marl, gypsum, clay and dolomite with salty layers. ΔP is the economical financial support that can save the capital of project. Total summation of ΔP is 169% that can extend 455m extra grouting. The huge amounts of salty formation (500,000,000 tons) need more TSM grouting. According to, very technical point S_C can modify the total cost. Grouting influence radius may be increased in order to decline the total cost of project through the S_C and ΔP in Table 1. Figure 4. demonstrates the S_C of S970301-7-18 that were loaded using the first Tri-axial test on 7days and retest on 18days ages σ_{ii} =7000 kPa. S970301-18 was broken till σ_{iii} =4400 kPa. Therefore, the ratio of $S_C=\sigma_{ii}/\sigma_{iii}$ may compute by ratio of stresses 7000/4400 that obtains the 1.6-time resistance increasing or S_C=160%. The mean P(x)=0.60 is computed by Table 1. That could not be satisfied the TSM financial support of project. If the P(x) is added by the S_C therefore the P(x) can improve into the 0.93 successful results. The ratio S_C=1.5 is the 50% economical beneficial rate in the total cost. S_C may obtain through the step grouting stages in duration of 6days. The 50% discount will be achieved without more cost or extra grouting. The S_C can take values 50% to 230% in Eq. (8).

5 CONCLUSION

Over 500,000,000 tons salty formations were placed in the GOTVAND Dam Lake. The initial layout was selected 10km upstream of GOTVAND station (HARZA 1968). TSM solution is the only economical technics that can be stabilized the salty domes. Economical constrains will be forced to make each borehole accurate and highly beneficial grouting. TSM has the two magnificent brilliant items that can challenge with another submitted layout. First is approved by salty concrete to make stone all salty regions in range of 55% to 95% (Turk *et al.* 2017, 2018). Second can announce to maximize the grouting efficiency in deep foundation engineering by S_C and proportion ΔP in Table 1. TGDF demonstrates the successful operation in the problematic salty formations. TGDF shows the screen of stabilization for the site manager that matches with Table 1. and Eq. (9). Probability are taken values $0.30 \leq P(x) \leq 0.50$ in all layers and $0.50 \leq P(x) \leq 0.65$ in the pure salty formation without Sc.

Figure 4. a) RTAT C: 300 kPa 7days-18days b) σ_{ii}= 7000 c) 18days σ_{iii}= 4400 kPa.

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