Effect of leaching on the dissolution of Al-Dour gypseous soil

Namir K.S. Al-Saoudi
Prof. Dr.,University of Technology, Baghdad, Iraq, namirks@yahoo.com

Layla Abed Alkareem Al- Banna
Formerly Research Student, University of Technology, Baghdad, Iraq

KEYWORDS: Gypseous soil, dissolution, leakage, permeability, soaking

ABSTRACT: Gypseous soils exist in many countries of the world concentrated mainly in arid and semi-arid regions, in Iraq it covers about 20-30 % of its total area. Gypseous soils are identified by their appreciable amount of gypsum ($CaSO_4.2H_2O$) and exhibit very stiff behaviour under dry conditions where cementation is developed between the gypsum and the soil particles, but may exhibit sudden loss in strength upon wetting.

The present paper focuses on the leaching process under different water pressures of a typical gypseous soil of gypsum content 66.4 % brought from Al- Doar city/ Iraq. A special setup was designed and manufactured providing various soaking and flow conditions. Samples were prepared at field dry unit weight, 12kN/m^3 and maximum Proctor dry unit weigh 15.2 kN/m^3. The leaching process was preceded by soaking period ranging from 1 to 5 days. The dissolution of gypsum was observed by measuring the total dissolved salts, TDS, and the sulphate content SO_3 under water pressures 3, 6, 9, 12 and 15kN/m^2.

The results revealed that samples prepared at field unit weight exhibited higher rates of dissolution of gypsum as compared to corresponding samples at maximum unit weight. The coefficient of permeability demonstrated a decreasing trend with increasing number of leaching cycles for both unit weights but their absolute values remain higher for samples at field unit weight.

1 INTRODUCTION

The geotechnical properties and the overall behaviour of gypseous soils have been investigated in many countries (Alphen and Romero, 1971; Nashat, 1990; Sheikha, 1994; Al-janabi 2006 and many others). The main concern was focused on the collapsibility of gypseous soils under different patterns of wetting conditions and various stress levels. The majority of the outcomes were concerned in identifying safe limits of the collapsibility for safety precautions during construction.

The collapsibility of gypseous soils results from the dissolution of different salts contained inside the mass of gypseous soil when it comes in contact with water. The dissolution will loosen the soil skeleton between the particles and creates a meta stable structure that facilitates the sliding of particles into a more dense state.

The leaching process and its consequences on the on the overall behavior of gypseous soil was investigated mainly through element tests performed using either Rowe consolidation cells (Abood, 1994; and many others), oedometer - permeability leaching apparatus and triaxial-permeability leaching apparatus were used by many authors (Al-Qaisee 2001; Al-Abdullah and Ibrahim 2001) and many others. Many researchers have manufactured special leaching apparatus testing samples of different sizes (Al-Obaydi 2003). The present paper demonstrates a special set up allowing soaking and leaching under different water pressures.

Leaching field tests are very limited, (Mikheeve etal. 1977; Petrukhin and Boldyrev 1978) performed plate load tests on different types of gypseous soils under long term wetting conditions. The outcomes of the field tests revealed that the deformed zone is 1 to 1.5 times the plate diameter and complete leaching of the gypsum from the soil does not occur.

The present paper sheds the light on the dissolution of gypsum after soaking under various water pressures for different time intervals.

2 MATERIALS AND TESTING

2.1 Soil Used

The soil used was brought from a site very close to the Sodium Sulphate Factory in Al-Doar in Salah- Aldeen governorate, Iraq. Disturbed samples were taken from a depth 0.5 to 1.0 m below natural ground level. The grain size distribution consists of 12 % gravel, 13 % sand and 75 % silt. According to the Unified Soil Classification System and the physical properties shown in Table 1, the soil is classified as ml (silt of low plasticity). The chemical analysis and the results of the results of the X-Ray diffraction are summarized in Table 2

Table 1. Physical properties of soil used

Property	Results
Natural Moisture Content, %	6.5
Specific Gravity	2.43
Classification of HCL Treated Specimen	ML
Atterberg Limits:	
Liquid Limit LL, %	35
Plastic Limit PL, %	32
Plastic Index	3
Field Unit Weight (γ_f) kN/m^3	12.88
Compaction Test (Max. γ_d)kN/m^3,$w_{opt.}$ %	
Standard	15.2,13.8
Modified	17.2, 10

Table 2. Chemical analysis and X ray diffraction

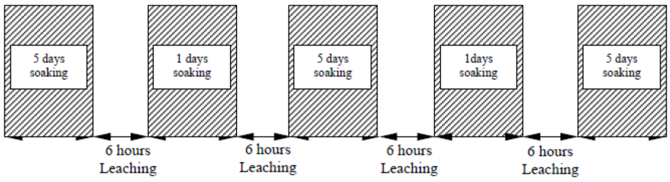
Test	Results
Total Sulphate content SO_3 %	36.04
Gypsum content %	66.4
CaO Content % using EDTA	26.18
Water of Crystallization W.O.C. % at 230^{0}C	16.2
pH	8.2
X ray Diffraction	gypsum, trace quartz

2.2 Test Setup

The test setup is a plastic container 2070 mm in height of square section with 150 mm side, consists of two chambers housing the mould of sample in between, the upper chamber is 1550 mm in height divided into five levels 300 mm apart with one outlet at each level. These outlets control the height of water at the required constant value during soaking or leaching. The lower chamber is 250 mm in height and of the same square section of the upper chamber; it works as a holder of the mould and as a base for the upper chamber. There is an outlet at the base of the lower chamber used to collect the water samples during the leaching process.

2.3 Sample Preparation and Testing

All samples were compacted to the to the required unit weight inside a steel mould 140 mm X 140 mm by 100 mm in depth. The plates of the mould are 2 mm thick. The mould was then placed in the setup with all accessories and the upper part of the setup filled with water to the required level. All samples were soaked for five days before the first leaching cycle, which lasted for 6 hours. The samples were then soaked for 1 day before the second leaching cycle started. The leaching process was repeated five times as shown in Figure 1



3 TEST RESULTS

3.1 Results of Soaking Tests

Two sets of tests were performed, the first consists of five identical specimens compacted at field unit weight $\gamma_{dry\ field}$ = 12kN/m^3, and three identical specimens at $\gamma_{dry\ max}$. = 15.2 kN/m^3. During the filling process of the upper chamber, water passes through the soil sample and collects in the lower chamber then the water in the upper chamber is fixed for each specimen at the required level providing soaking water pressures of 3, 6, 9, 12 and 15 kN/m^2. According to the sequence of soaking and leaching stages shown in Figure 1, water samples were collected after each soaking period and the amount of soluble salts were determined as shown in table 3.

Table 3 Dissolution results of soluble salts after different soaking periods

Density kN/m^3	Pressure kN/m^2	Soluble Salt	Days of soaking				
			5	1	5	1	5
γdry field =12 kN/m^3	15	'SO_3	1.40	1.10	1.25	0.80	0.89
		"TDS	3450	2450	2950	1800	2300
	12	SO_3	1.58	1.04	1.20	0.72	0.78
		TDS	4750	2300	2750	1650	2150
	9	SO_3	1.62	0.96	1.13	0.66	0.71
		TDS	5750	2200	2600	1450	1900
	6	SO_3	1.68	0.91	0.99	0.6	0.66
		TDS	6250	2100	2350	1350	1600
	3	SO_3	1.75	0.78	0.94	0.53	0.59
		TDS	6750	2900	2100	1200	1400
γdry field =12 kN/m^3	15	SO_3	0.98	0.8	0.91	0.5	0.73
		TDS	2150	1700	2100	1500	1650
	9	SO_3	1.10	0.72	0.82	0.59	.64
		TDS	2700	1600	2000	1350	1500
	3	SO_3	1.15	0.68	0.77	0.50	0.55
		TDS	4000	2150	1700	1100	1250

The table shows that the first 5 days soaking exhibits higher concentrations as compared to the following soaking periods. These observations are valid for all soaking pressures and for the two densities. Both soluble salts show an increasing trend with decreasing soaking pressure. These results are explained in terms of the time and rate of flow of water. At low water pressure, slow rate of flow occurs giving more chance for the salts to be washed out of the soil

3.2 Results of Leaching Tests

After each soaking period a 6 hour leaching was carried out. The leaching process was performed under water pressures 3, 6, 9, 12 and 15 kN/m^2 separately using constant head principles. Figures 2 and 3 demonstrate the five stages of leaching in terms of percentage reduction in SO_3 and TDS following each soaking period.

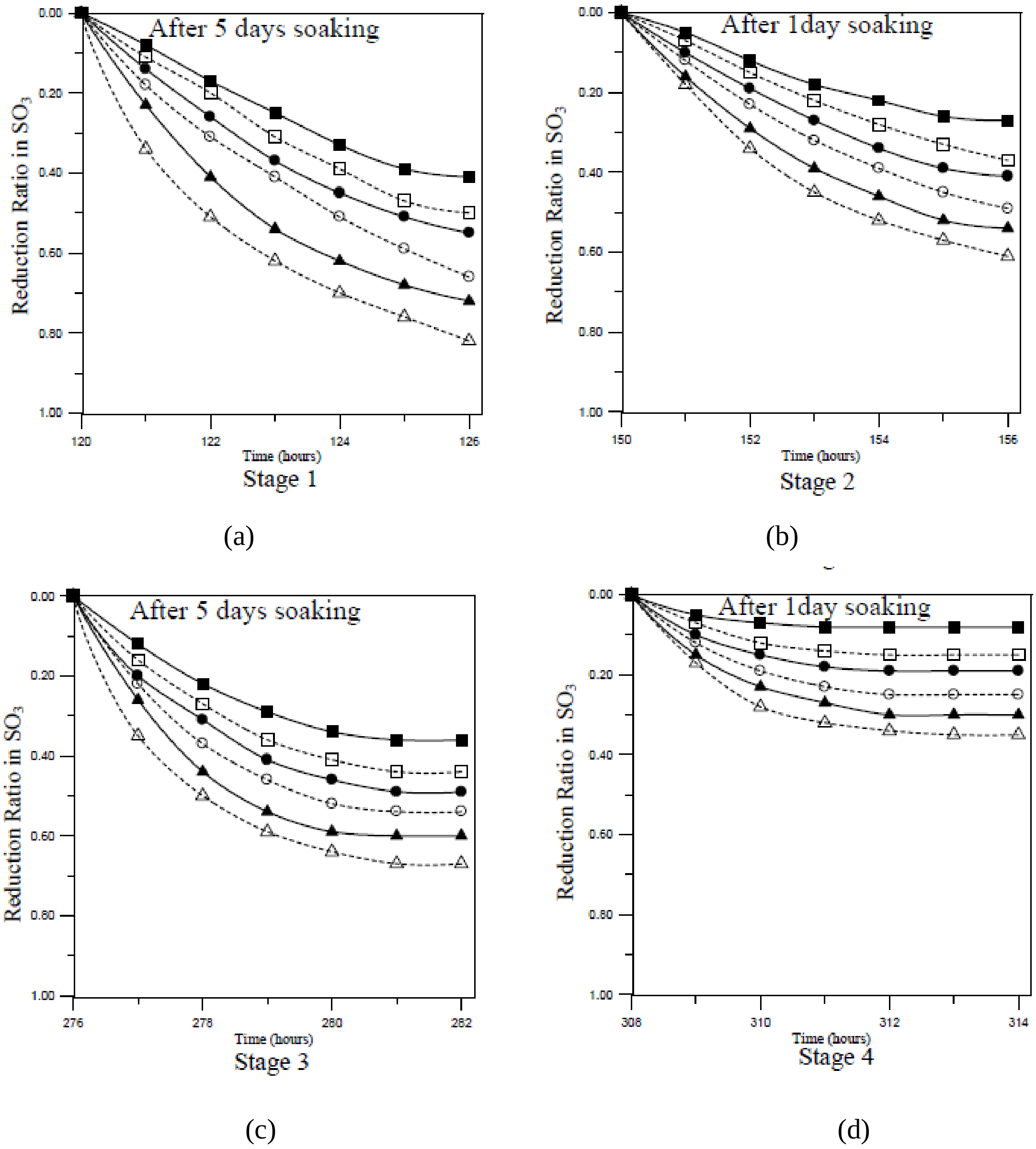
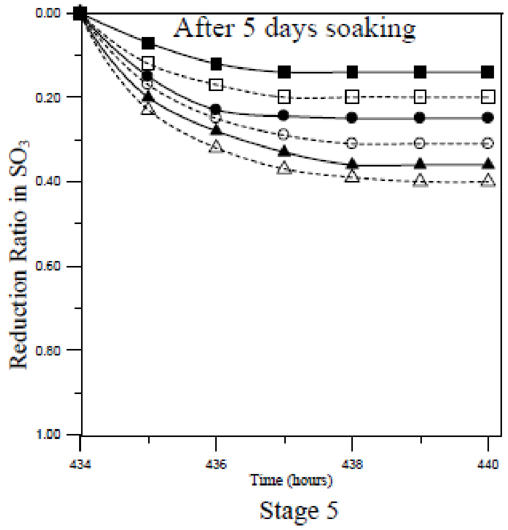


Figure 2. Reduction in SO_3 versus time for five leaching stages



(e)

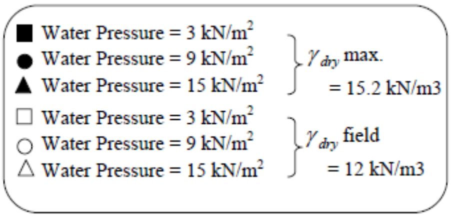


Figure 2. Reduction in SO_3 versus time for five leaching stages

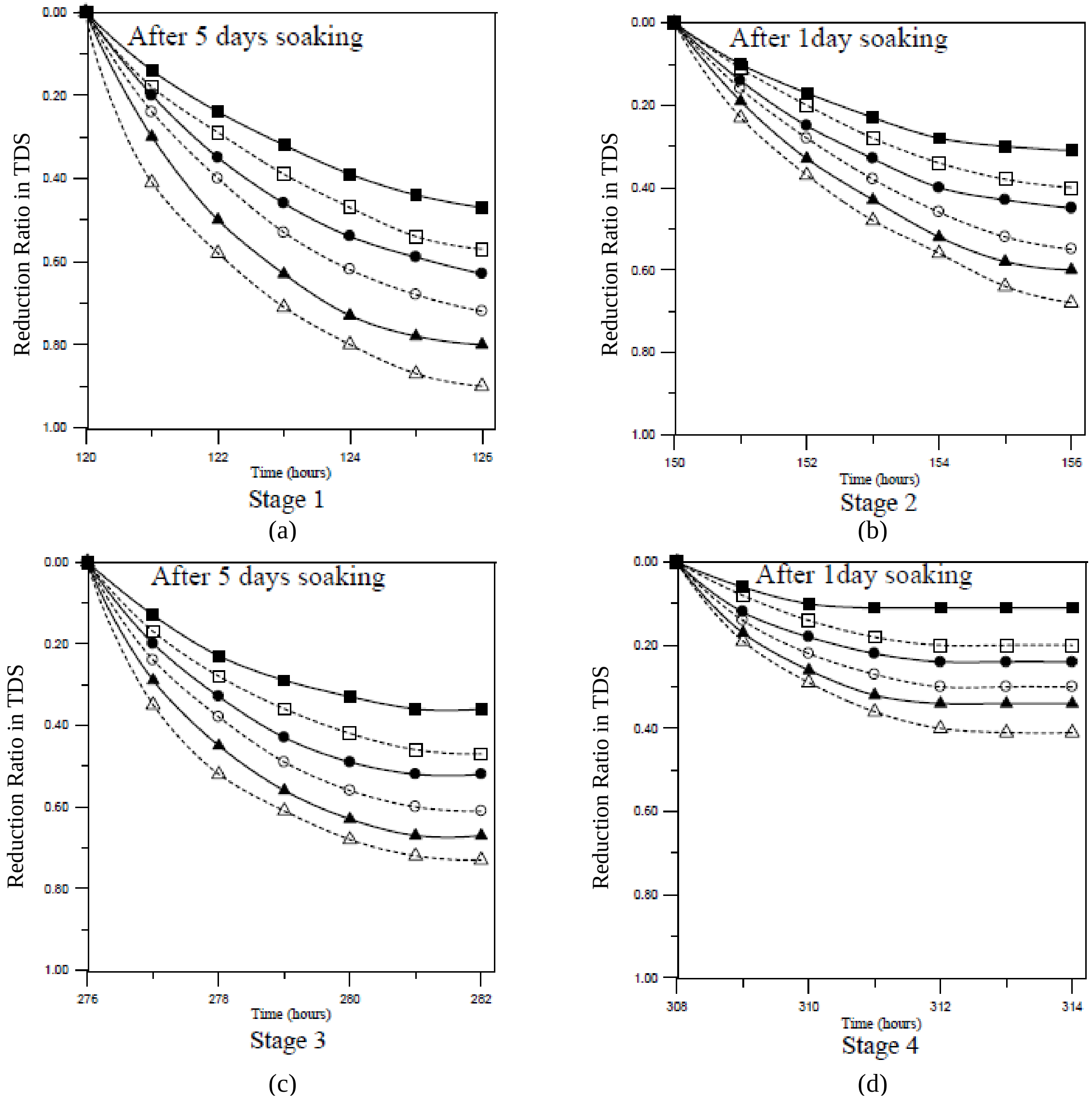
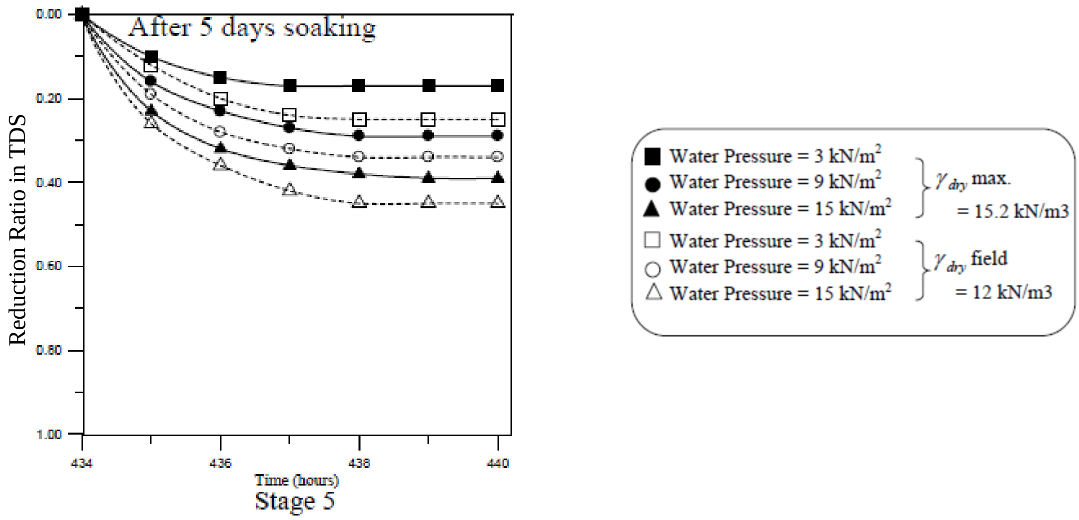


Figure 3. Reduction in TDS versus time for five leaching stages



(e)

Figure 3. Reduction in TDS versus time for five leaching stages

Stage 1 of leaching started after 120 hours of soaking, lasted from 120 to 126 hours, as shown in Figures 2a and 3a. Leaching begins with a high rate of dissolution then decreases gradually to a slower rate after 6 hours. The highest value occurred at water pressure 15 kN/m^2 and unit weight 12 kN/m^3 .Stage 2 started after 24 hours soaking at 150 hours and ended at 156 hours, the amount in reduction of SO_3 and TDS and rate of change with time is much less than Stage 1. Stage 3 of leaching started after 120 hours soaking at 276 hours and extended to 282 hours. In this stage, Figure 3a and 3b, more salts were dissolved during the 5 hours of soaking and the leaching demonstrated higher reduction in SO_3 and TDS as compared to Stage 2, also the amount of reduction reached to a stable stage after 4 hours leaching. Stage 4 of leaching started after 26 hours of soaking at 308 hours and extended to 314 hours. During this period the reduction ratio of salts, SO_3 and TDS did not exceed 0.4 and the reductions in both salts reached stable values after 3 hours as shown in Figures 4a and 4b. The final stage of leaching, Stage 5, started after 120 hours of soaking at 434 hours and extended to 440 hours. The 6 hours of leaching exhibited the least amount of reduction of both SO_3 and TDS as compared to the previous leaching stages. Stable values of reduction of SO_3 and TDS were noticed after 3 hours as shown in Figures 5a and 5b. In all figures the lower density, field dry unite weight 12 kN/m^3 exhibited higher reduction of SO_3 and TDS as compared to the dry unit weight of 15.2 kN/m^3.

Table 4 demonstrates the percentage of gypsum, SO_3 and TSS before the first leaching stage and at the end of the last leaching stage. It can be seen that the gypsum content initially has a consistent value around 66% and this decreases due to the five stages of leaching according to the applied water pressure. In other words, the higher the water pressure, the higher is the hydraulic gradient and hence the higher is the washed-out percentage of gypsum. Considering the case of field density 12.0 kN/m^3, the percentage loss of gypsum is clearly 38.26 at water pressure 15 kN/m^2, when the water pressure is 3 kN/m^2, the generated flow velocity at this water pressure is very slow and thus not capable of washing out a substantial amount of gypsum and hence the percentage loss of gypsum was 10.21.

A similar trend was noticed for the case of the maximum dry unit weight of 15.2 kN/m^3. At water pressure of 15 kN/m^2 the percentage loss in gypsum is 20.19, much less than the corresponding value at the field unit weight of 12.0 kN/m^3. Furthermore, at water pressure of 3 kN/m^2, the percentage loss in gypsum is 6.34, much less than the corresponding value at the field unit weight of 12.0 kN/m^3. Intermediate results are obtained between the extreme cases for both unit weights.

Table 4. Results of Gypsum %, SO_3 % and TSS % before and after the five leaching stages

Density kN/m^3	w.p kN/m^2	Before leaching			After leaching			Loss of Gypsum %
		Gypsum %	SO3 %	TSS %	Gypsum %	SO3 %	TSS %	
γ *dry field 12 kN/m^3*	15	66.78	31.06	67.71	41.23	19.18	41.99	*38.26
	12	67.15	31.23	68.08	47.59	22.13	48.47	29.13
	9	66.45	30.91	67.07	52.26	24.31	52.75	21.35
	6	68.12	31.68	69.06	57.62	26.80	58.69	15.41
	3	67.63	31.45	68.87	60.72	28.24	61.85	10.21
γ *dry max 15.2 kN/m^3*	15	67.82	31.54	68.76	54.13	25.18	55.14	20.19
	9	66.55	30.95	67.47	57.84	26.90	58.64	13.08
	3	66.28	30.83	67.52	62.08	28.87	63.22	6.34

Figure 4 demonstrates an increasing trend in the percent loss of gypsum with increasing leaching water pressure. The figure clearly indicates a higher rate for the lower density. The coefficient of permeability was determined for each 6 hours leaching stage as shown in Figure 5. After each soaking period a gradual decrease in the coefficient of permeability was noticed, and the longer soaking period becomes more significant at higher water pressures. The sample of maximum dry unit weight at low water pressure demonstrated marginal decrease during the five stages of the leaching process.

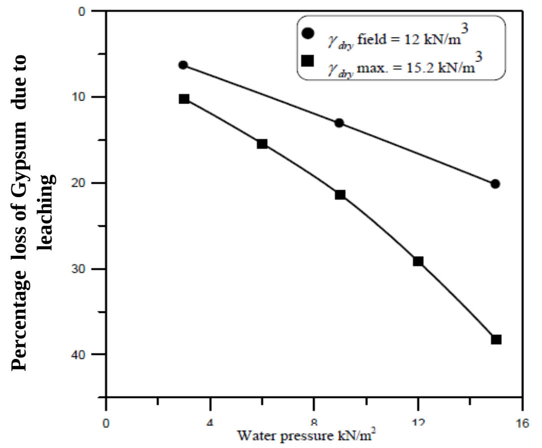


Figure 4. Percentage loss of gypsum versus water pressure

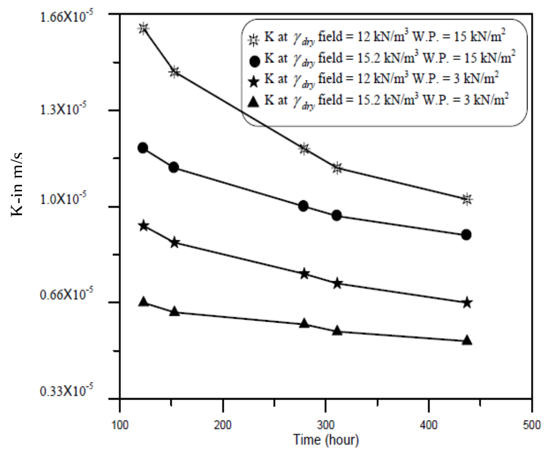


Figure 5. Coefficient of permeability versus leaching time

4 Conclusions

Soaking of samples under water pressures ranging between 3 to15 kN/m^2 tends to dissolve salts and breakdown the existing cementation bonds. The leaching process following the soaking period demonstrated higher percentage loss of gypsum under 15 kN/m^2 water pressure that gradually decreased with decreasing water pressure down to 3 kN/m^2. The amount of salts washed out during leaching decreases with increasing soaking stages. The coefficient of permeability demonstrated a decreasing trend after each soaking period for both samples prepared at field density and at maximum dry density. The influence of leaching was significant for samples at field density at high water pressure. Marginal difference was observed at maximum dry unit weight under low water pressure.

REFERENCES

Abood, M.K. (1994). Treatment of gypseous soil with sodium silicat. MSc. Thesis, University of Technology. Baghdad.Iraq.

Al- Qaisy, G.S.H. (2001). Leaching collapse of gypseous soils. MSc. Thesis . University of Baghdad. Iraq

Al-Abdulla, S.F. I. & Ibrahim, K.H. (2001). Shear strength characteristics of gypseous soils during leaching and loading. The Iraqi journal of civil engineering, 1. 278-296.

Al-Janabi, K.R.M. (2006). Laboratory leaching process modeling in gypseous soils using artificial neural network (ANN). PhD. Thesis ,University of Technology. Baghdad.Iraq.

Al-Obaydi, Q.J. (2003). Studies in geotechnical and collapsible characteristics of gypseous soil. MSc. Thesis, University of Al-Mustansiria . Baghdad. Iraq.

Alphen, J.G.V.& Romero, F.R. (1971). Gypsiferous soils notes on their characteristics and management. International Institute for land reclamation and improvement, Wageningen, Netherlands.

Mikheev, V.V., Petrukhin, V.P. & Boldirev, G.V. (1977). Deformability of gypseous soils. Procedding of the ninth ICSMFE . 1. 211-214

Nashat, I.H. (1990). Engineering characteristics of some gypseous soils in Iraq.PhD. Thesis, University of Baghdad. Iraq.

Petrukhin, V.P. & Boldirev, G.V. (1978). Investigation of the deformability of gypsofied soils by static load. Soil mechanics and foundation engineering . 15. 178-182.

Sheikha, A.A.H. (1994).The collapsibility of gypseous soil and the effect of leaching on its behaviour. MSc. Thesis, University of Technology. Baghdad.Iraq