Journal of Structural Engineering and Geotechnics,
2 (1), 49-54, Winter 2012

# The Study of Improvement of Dispersive Soil Using Magnetic Field

S. F. Ashrafi*[a], M. Behzad[a], A. Naseri[a], H. Ghafarian Malmiri[b]

[a]*Department of Water Science Engineering, Shahid Chamran University, Ahwaz, Iran*
[b]*Department of Material Science And Engineering, Sharif University of Technology, Tehran, Iran*
Received March 2012; Accepted June 2012

**Abstract**

In this study, the feasibility of using magnetic technology to reduce the dispersion of soil has been investigated. The reference treatment was potable water and 3 magnetic water devices (with different magnetic intensities) were used for magnetizing the potable water. The results showed that the magnetic field has a significant effect in order of 5 percent on increasing of magnesium concentration in soil columns and the calcium concentration in magnetic treatment was more than the reference treatment. It seemed that improving in hydrogen bonding between water molecules and clay particles and water trapping in soil caused reduction of salt in the soil. According to the increase of calcium and magnesium bivalent Cations in the soil, it is suggested that the use of magnetic field could improve soil's dispersion and decrease the degree of soil's dispersion.

***Key word***: Dispersive soil, Magnetic field, cations movement, Water

## 1. Introduction

Dispersive soils are unstable soils that cause failure in earth dams. In such cases, exposing of soil to water and flow of water in soil pores causes suspension of clay particles in water and soil's erosion [1]. With regard to spreading of dispersive soil in arid and semi-arid regions across the Earth and due to use of dispersive soil as a construction material, many corrective methods have been used to control dispersion of soil. The most common method is using of chemical materials such as lime [2]. However, using lime in some cases is associated with some disadvantages. For example, if the soil contains sulfate ions or stabilized soil is exposed to water containing sulfate, the presence of lime causes an increase of swelling layer and reduction in soil strength [3]. In most studies it is reported that the sodium replacement by calcium ions in mineral soils is a useful method for reducing soil dispersion [4]. The important question that must be answered is the possibility of increasing the soils strength (decrease the degree of dispersion) without using a chemical method.

*Corresponding Author Email: ashrafi_ma90@yahoo.com

In recent years, magnetic field technology has been used for hard water improvement, especially at arid and semi-arid regions because the water hardness in these regions is more than other regions. In this method, nothing is added to or extracted from water but the presence of a magnetic field, which causes the configuration of water molecules' electrical charge will be changed [5]. These modified water molecules can change the content of ions in the soil. In this research, the effects of three magnetic fields with different intensities on the cations' movement in the soil are studied and the results are compared with reference treatment without any magnetic field.

## 2. Methods and Materials

In this research, a completely randomized plan consisting of 4 treatments and 3 repetitions was conducted in Shahid Chamran University for investigation of the effect of magnetic water on the solute movement in the soil. The water was supplied by potable water network and experiments were carried out on the soil with fine grain texture (research farm no.1 in water faculty of Shahid Chamran University). At first, sampling from the soil, air

drying and passing soil thorough sieve No. 10 were carried out in order to determine the physical and chemical properties of the soil. Several properties of the soil are illustrated in Tables 1 to 3.
In Tables 1 to 3,soil texture, the acidity, electrical conductivity, sodium and potassium concentrations are determined by using a hydrometric method,pH meter, and EC meter, respectively, and other ions are determined using titration method [6].
For preparation of soil columns, 12 (4 treatments and 3 repetitions) high pressure plastic tube (10 cm in diameter and 20 cm in height) were used. In order to prevent preferential flow, the tube walls were imbued by grease. In addition, the bottoms of tubes were closed by infiltration paper and soil with 15 cm height and bulk density close to Table 1 was compressed into the tubes. Figure 1 illustrates the worktable that was designed to collect drained water from the samples more easily. In the following process, the main water supplying pipe was divided to 4 branches as different treatment (3 magnetic devices and 1 reference treatment) and each branch was divided into 3 sub-branches to make repetitions (3 repetitions). Figure 2 illustrates the schematic plan of water supply system.
In this research, 3 inside piping magnetic devices with laboratory size (0.5 inch in diameter) were used for magnetization of potable water (Figure 3). The characteristics of magnetic devices are as follows:

- RPM 50: magnetic sediment remover device with ring magnet, 0.05 Tesla intensity and 24 cm in length (treatment 1).
- Elcla: magnetic device with net-like magnet, 0.16 Tesla intensity and 9.2 cm in length (treatment 2).
- Aqua Correct: magnetic device with ring magnet, 0.13 Tesla intensity and 20 cm in length (treatment 3).

The reference treatment was the potable water without any magnetization by magnetic field. The duration of experiments was 35 days [7] and during this period there was a constant 2 cm height of water over the soils columns.

Table 1: Soil physical analysis results

| Density (gr/cm$^3$) | Bulk Density (gr/cm$^3$) | Soil Texture | Sand Percent | Silt Percent | Clay Percent |
|---|---|---|---|---|---|
| 2.62 | 1.5 | fine grain | 39 | 37 | 24 |

Table 2: Chemical properties of the soil

| $SO_4^{2-}$ (meq/lit) | $HCO_3^-$ (meq/lit) | $Co_3^{2-}$ (meq/lit) | $Cl^-$ (meq/lit) | $K^+$ (meq/lit) | $Na^+$ (meq/lit) | $Mg^{2+}$ (meq/lit) | $Ca^{2+}$ (meq/lit) | EC (ds/m) | pH |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 3.5 | 0 | 32.6 | 0.6 | 12 | 11 | 18 | 4.11 | 7.7 |

Table 3: Potable water characteristics that has been used in the experiments

| $SO_4^{2-}$ (meq/lit) | $HCO_3^-$ (meq/lit) | $CO_3^{2-}$ (meq/lit) | $Cl^-$ (meq/lit) | $K^+$ (meq/lit) | $Na^+$ (meq/lit) | $Mg^{2+}$ (meq/lit) | $Ca^{2+}$ (meq/lit) | EC (ds/m) | pH |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 0 | 13.5 | 13.5 | 11 | 11 | 11 | 11 | 11 |

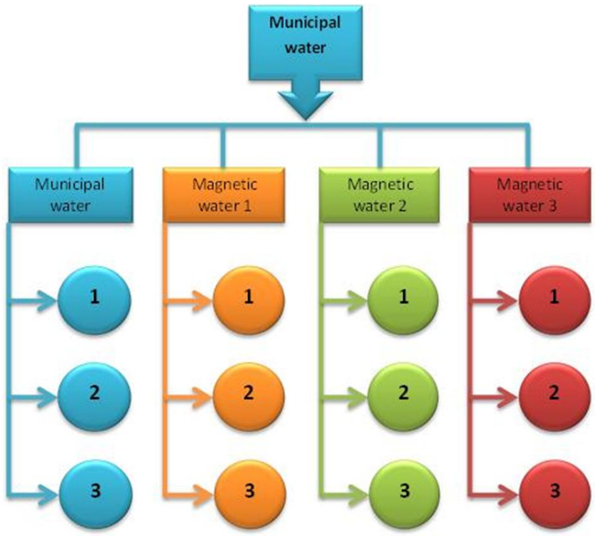
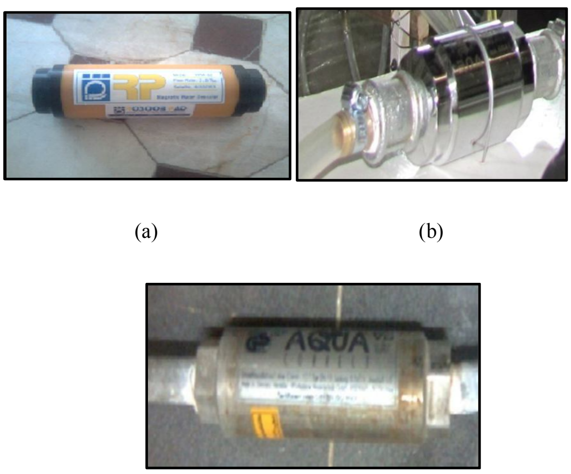



Figure 1: Schematic illustration of water pipes.

Figure 2: Overview of the experiment is working.




(a) (b)

(c)

Figure 3: (a): The RPM 50 magnetic device (b): Elcla magnetic device, (c): The Aqua Correct magnetic device.

After the experiment period, the concentration of calcium, magnesium, sodium and potassium were measured in the soil columns and data were averaged at each treatment. In the proceeding process, using Duncan test, data analysis was performed and if a significant difference was observed between treatments, then LSD test was used for multiple comparisons between the data (all of the statistical analysis were conducted by SPSS16 software). In this method, if Sig (signification) amount (variance analysis table or software output of LSD test) was less than considered probability level, therefore that independent factor (here is magnetic water) has significant effect on the dependent factor (here is concentration of cations). This situation means significant difference between averages on considered probability level. Otherwise (if Sig amount is greater than considered probability level) there is not significant effect between averages of treatments.

## 3. Results and Discussion

*1 - Effect of magnetic treatments on the concentration of sodium in the soil columns:*

The effect of magnetic treatments on the sodium concentration in the soil columns is shown in Figure 4. In this figure, the reference and the first magnetic treatments have the least amount of sodium in the soil (7.23 meq/l).The second and third magnetic treatments have 0.69% and 1.1% sodium concentrations more than reference treatments, respectively. However, as can be seen, the sodium variations in treatments is very low. According to the table 4 the magnetic water has no significant effect on the concentration of sodium of the soil columns, because sig is greater than considered significant level (here is 0.05). The decreasing of sodium concentration in the soil solution by magnetic water has been reported by Zangeneh, Seliha and Boogatin [8-10].

Table 4: Data variance analysis of Sodium concentrations in the soil columns for different treatments

| **Test of Between-Subjects Effects** | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: **Na** | | | | | |
| **Source** | **Type ||| Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 0.011[a] | 3 | 0.004 | 0.040 | 0.988 |
| Intercept | 632.636 | 1 | 632.636 | 7.029E3 | 0.000 |
| Treatment | 0.011 | 3 | 0.004 | 0.040 | 0.988 |
| Error | 0.720 | 8 | 0.090 | | |
| Total | 633.367 | 12 | | | |
| Corrected Total | 0.731 | 11 | | | |
| R Squared= 0.015 (Adjusted Squared=-0.355) | | | | | |

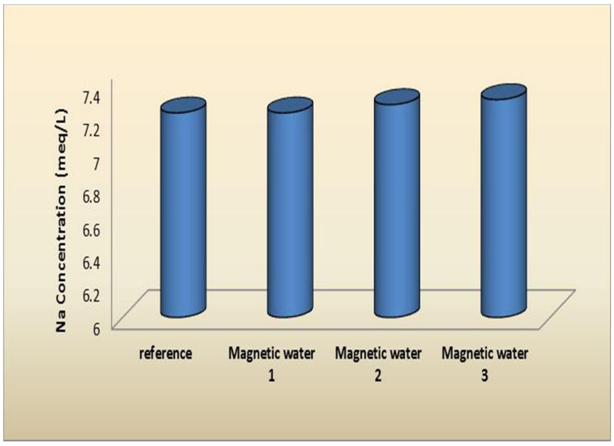



Figure 4: Average concentration of sodium in the soil columns.

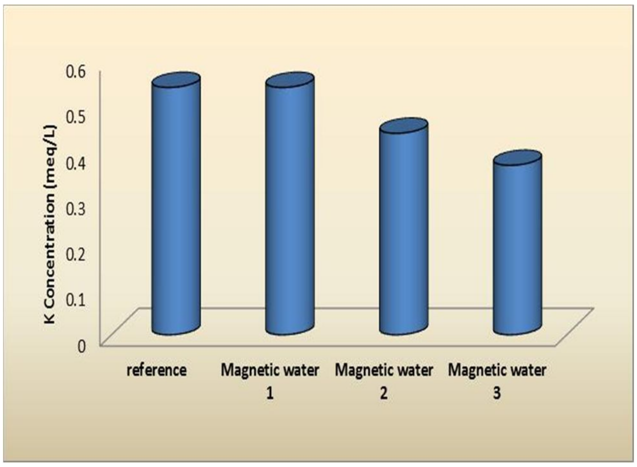



Figure 5: Average concentration of potassium in the soil columns.

*2 - Effect of magnetic treatments on the concentration of potassium in the soil columns:*

As Figure 5depicts, the average amount of potassium in the soil columns changesbetween0.37 and0.54 (meq/l). The reference and the first magnetic treatments have the highest amount of potassium. Average potassium concentrations in the second and third magnetic treatments are 18% and 31% less than reference treatment. Table 5 showed no significant effect of magnetic water on the potassium concentration of the soil columns, because sig is greater than considered significant level (here is 0.05)..Zangeneh [8] also found that the concentration of potassium in the soil solution decreased in magnetic treatments.

Table 5: Data variance analysis of potassium concentrations in the soil columns for different treatments

| **Test of Between-Subjects Effects** | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: **K** | | | | | |
| **Source** | **Type ||| Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 0.062[a] | 3 | 0.021 | 1.782 | 0.228 |
| Intercept | 2.679 | 1 | 2.679 | 230.955 | 0.000 |
| Treatment | 0.062 | 3 | 0.021 | 1.782 | 0.228 |
| Error | 0.093 | 8 | 0.012 | | |
| Total | 2.834 | 12 | | | |
| Corrected Total | 0.155 | 11 | | | |
| a.R Squared= 0.401 (Adjusted Squared=0.176) | | | | | |

*3 - Effect of magnetic treatments on the concentration of calcium in the soil columns:*

According to table 6, magnetic water has a significant effect on the calcium concentration in the soil columns, because sig is greater than considered significant level (here is 0.05). Figure 6 shows that the amount of calcium in the reference treatment is 4% less than other treatments. Zangeneh [8] and Seliha [9] showed an increase in calcium concentration in magnetic treatments while Gehr [11] reported inversely.

Table 6: Data variance analysis of calcium concentrations in the soil columns for different treatments

| Test of Between-Subjects Effects | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: Ca | | | | | |
| Source | Type ||| Sum of Squares | df | Mean Square | F | Sig. |
| Corrected Model | 0.062[a] | 3 | 0.021 | 0.071 | 0.974 |
| Intercept | 295.021 | 1 | 295.021 | 1.006E3 | 0.000 |
| Treatment | 0.062 | 3 | 0.021 | 0.071 | 0.974 |
| Error | 2.347 | 8 | 0.293 | | |
| Total | 297.430 | 12 | | | |
| Corrected Total | 2.409 | 11 | | | |
| a.R Squared= 0.026 (Adjusted Squared=-0.339) | | | | | |

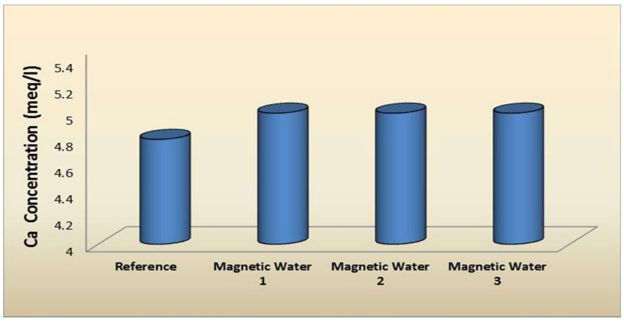



Figure 6: Average concentration of calcium in the soil columns.

*4 - Effect of magnetic treatments on the concentration of magnesium in the soil columns:*

As Figure 7 illustrates, the least amount of the magnesium concentration in the soil columns occurs in reference treatment (2 meq/l). The amount of magnesium concentration in the third treatment was 80% greater than the reference treatment. According to the table 7, magnetic water has a significant effect (in order 5%) on the magnesium concentration of soil columns, because sig is less than considered significant level that (here is 0.05).The same results about magnesium concentration were reported by Zangeneh [8].

Table 8 shows no significant effect in magnetic treatments. But results showed a significant effect in order 5% between reference treatment and magnetic treatments. Due to the effect of magnetic water on water electrical charge, hydrogen bounding in magnetic water is greater than ordinary water [8].Therefore, increasing of sodium, calcium and magnesium concentrations in the soil columns maybe caused by stronger hydrogen bounding between water and clay molecules. Water trapping between soil particles in magnetic treatments is another reason which can slow the movement of solutes in the soil and decrease the drainage from bottom of the soil columns.

Table 7: Data variance analysis of magnesium concentrations in the soil columns for different treatments

| **Test of Between-Subjects Effects** | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: **Mg** | | | | | |
| **Source** | **Type ||| Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 4.650[a] | 3 | 1.550 | 14.419 | 0.001 |
| Intercept | 111.630 | 1 | 111.630 | 1.038E3 | 0.000 |
| Treatment | 4.650 | 3 | 1.550 | 14.419 | 0.001 |
| Error | 0.860 | 8 | 0.108 | | |
| Total | 117.140 | 12 | | | |
| Corrected Total | 5.510 | 11 | | | |
| a.R Squared= 0.844 (Adjusted Squared=0.785) | | | | | |

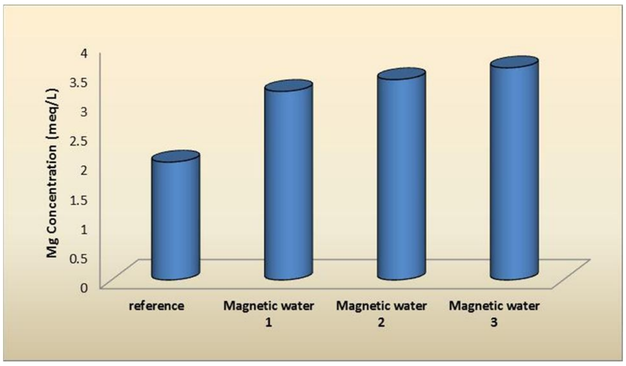



Figure 7: Average concentration of magnesium in the soil columns.

Table 8: Multiple comparison between the average amounts of magnesium concentration in the soil treatments

| Multiple Comparisons | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dependent Variable: Mg | | | | | | | |
| | | | | | | 95% Confidence Interval | |
| | (I) Treatment | (J) Treatment | Mean Difference (I-J) | Std. Error | Sig. | Lower Bound | Upper Bound |
| LSD | 1 | 2 | -0.2000 | 0.26771 | 0.476 | -0.8173 | 0.4173 |
| | | 3 | -0.4000 | 0.26771 | 0.173 | -1.0173 | 0.2173 |
| | | 4 | 1.2000* | 0.26771 | 0.002 | 0.5827 | 1.8173 |
| | 2 | 1 | 0.2000 | 0.26771 | 0.476 | -0.4173 | 0. 8173 |
| | | 3 | -0.2000 | 0.26771 | 0.476 | -0.8173 | 0.4173 |
| | | 4 | 1.4000* | 0.26771 | 0.001 | 0.7827 | 2.0173 |
| | 3 | 1 | 0.4000 | 0.26771 | 0.173 | -0.2173 | 1.0173 |
| | | 2 | 0.2000 | 0.26771 | 0.476 | -0.4173 | 0.8173 |
| | | 4 | 1.6000* | 0.26771 | 0.000 | 0.9827 | 2.2173 |
| | 4 | 1 | -1.2000* | 0.26771 | 0.002 | -1.8173 | -0.5827 |
| | | 2 | -1.4000* | 0.26771 | 0.001 | -2.0173 | -0.7827 |
| | | 3 | -1.6000* | 0.26771 | 0.000 | -2.2173 | -0.9827 |
| Based on observed means.<br>The error term in Mean Square (Error)= 0.108.<br>*. The mean difference is significant at the 0.05 level. | | | | | | | |

## 4. Conclusion

In this study, the effect of magnetic water on the movement of cations in the soil was investigated using 4 treatments and 3 repetitions for 35 days. It is notable that the difference between magnetic devices (due to different magnetic field intensities and magnets arrangement in magnetic device) has not been considered in our experiments [7]. The following conclusions were obtained:

1- After 35 days, the magnetic water only has significant effect (5%) on the magnesium concentration in the soil columns. Magnesium concentration in third, second and first magnetic treatments were 80%, 70% and 60% greater than reference treatment respectively.
2- The calcium concentration in reference treatment was 4% less than magnetic treatments.
3- Variation of sodium concentration was very low in all treatments. Maximum difference was observed between third magnetic treatment and reference treatment (1.1% greater than those of reference treatment).
4- In this study, only potassium concentration in reference treatment was greater than magnetic treatments. The potassium concentration in second and third magnetic treatments was 18% and 31% less than reference treatment.

As can be observed, the amounts of calcium and magnesium in magnetic treatments have been increased. Therefore soil resistance could be improved by this method [4] while no materials add to the soil. So, the magnetic technology can be used to improving dispersive soils without any chemical additions. Nevertheless, to find the effect of magnetic field on liquid limit (LL), plastic limit (Pl) and shrinkage limit (SL) more experiments are needed.

Appreciation and Thanks:
The authors would like to thank Shahid Cahmran University, Ahwaz, Iran, for the financial support and research facilities used in this work. We are grateful for the support provided by department of Water Science Engineering.

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