Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 42-50, 6, 2024
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Araştırma Makalesi

IJANSER

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 42-50, 6, 2024
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Research Article

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

Determination of Moisture Condition Values of Bentonite Material Mixed with Salt in Different Water Contents

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(Received: 09 July 2024, Accepted: 24 July 2024)

(4th International Conference on Scientific and Academic Research ICSAR 2024, July 19 - 20, 2024)

ATIF/REFERENCE: Dağlı, E., Kaya, A. F., Türkal, B. & Aydoğan, İ. (2024). Determination of Moisture Condition Values of Bentonite Material Mixed with Salt in Different Water Contents. *International Journal of Advanced Natural Sciences and Engineering Researches,* 8(6), 42-50.

Abstract **–** Strength tests available to determine the strength of soils can sometimes be time consuming or test equipment may not be available. In this case, alternative experiments can be a savior. In terms of the strength of fillings, there is the MCV test as an alternative to the CBR test. In this study, high plasticity bentonite material was mixed with different amounts of salt (5, 10, 15, 20, 25 and 30%). To determine the physical properties, a standard proctor test was performed specifically for each mixture. MCV test was performed on the mixtures prepared at certain multiples of the optimum water contents obtained from the Proctor test (0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4 and 1.5). In this way, the effect of water content change on MCV was also examined. According to the results obtained, if the water content is more than 20% of the optimum water content, BT20, BT25 and BT30 mixtures do not meet the MCV = 8.5 value recommended for filling, while BT5, BT10 and BT15 mixtures meet this condition. BT20 mixture give best performance compared to other mixture when taking into consideration of equation created between water content and MCV. It was concluded that in mixtures with lower salt content, water content tolerance is higher than in mixtures with high salt content.

Keywords – Clay, MCV, Proctor, Salt, Water Content.

I. INTRODUCTION

Modeling of engineering structures is not just about designing and manufacturing the structure. What is meant by modeling basically includes field experiments, laboratory experiments and project analysis via software. The current world population has exceeded 8 billion [1]. Therefore, this large human population needs housing, education, social activities, hospitals, etc. It is necessary to build new buildings to meet the needs. However, although there is sufficient financing in the world to meet this demand, there may not be enough space. This situation reduces the designer's luxury in choosing land. In other words, it became necessary to construct buildings on lands with weak soils. However, it is not appropriate to build a multi-storey building on weak soils without stabilizing them in today's conditions. In this respect, these soils with low strength can be stabilized by various methods and as a result of this process, they become able to carry the building loads on them. Among the soil types, clay has the lowest strength. High plasticity clays have high settlement amounts and high swelling etc. Therefore, it has the potential to be one of the main architects of destructive effects for buildings.

The subject of stabilization of high plasticity clay soils has been studied intensively by many researchers. Due to the nature of this type of soil, their strength tends to increase when mixed with most materials that may be additive. The engineering properties of clayey soils largely depend on the water content. There is also the possibility that water content may change under field conditions. Therefore, it is useful to examine the effect of water content on material strength. A ground that meets the limits given by regulations in any water content will not pose a problem in terms of use. Changing the water content may reduce the strength, but it would be appropriate to investigate to what level it is reduced.

In manufacturing such as road filling, the Karayolları Highways Technical Specification [2] developed by our country is used. Specification rules are essential. The suitability of the filling material to be used is controlled by this specification. The main tests applied in filling material control are California Transport Rate, unconfined compression strength, sieve analysis, consistency limits, nuclear density, sand box (cone) tests. At this point, it would be appropriate to use whatever experimental set is available as an engineer. Although there is a study examining the calibration curve on the MCV number, this study is only for an unstabilized clay sample. Studies of MCV are not that much [3-8].

In this study, different amounts of salt (5, 10, 15, 20, 25 and 30%) were added to high plasticity clay. Compaction characteristics of salt-added mixtures were also examined. Samples were prepared with water contents at different multiples of the optimum water content values obtained in all mixtures (0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4 and 1.5) and were subjected to MCV tests. In this way, both the effect of salt addition on the MCV number on clay and the effect of water content changes on the MCV value of each mixture were examined.

II. MATERIALS

High plasticity bentonite was used in this study. The reason for this choice is the high probability of obtaining successful results in stabilizing this material with most additives and strengthening the engineering properties of a weak soil. The bentonite material used is shown below. Materials of bentonite and salt are shown in Fig 1.

Fig. 1 Image of salt and bentonite

Commercially produced salt in Figure 2 was used as an additive material. When the chemical composition of this salt is examined; 38.758 g sodium, 8 mg potassium, 24 mg calcium and 0.33 mg iron were found.

III. PROCTOR TEST

This test is performed according to ASTM D698-12 standard [9]. In the compaction experiment according to Figure 2a, the sample and additives were placed on a tray. Then, water with a certain water content was added to this mixture and mixed thoroughly so that the entire mixture was homogeneous. Afterwards, it was compacted in the proctor mold with a volume of 944 cm^3 with the help of a standard tamper, as seen in Figure 2b. Compaction was set to 3 layers and 25 hits per layer. After a total of 75 hits, the mold + wet soil mass was measured and the samples in Figure 2c were taken to determine the water content from different layers. Due to the nature of the experiment, this process was repeated 4 more times. Figure 2 shows the application stages of the proctor experiment in detail.

Fig. 2 Proctor test stages a) Mixing and compaction b) compaction c) moisture cans for water content

In this study, a proctor test was conducted for different salt contents. The maximum dry density and optimum water content values found according to the results obtained are summarized in Table 1. Mixtures were coded as BT5, BT10, BT15, BT20, BT25 and BT30. Details of them were defined in this Table 1. Accordingly, as the salt content increased in the mixture, the optimum water content decreased and the maximum dry density increased.

Table 1. Proctor test results for the mixtures

Mixture Code	**Mixture Detail**	**w_{opt} (%)**	**ρ_{dmax} (g/cm^3)**
BT5	Bentonite + 5% salt	34.5	1.27
BT10	Bentonite + 10% salt	29.5	1.30
BT15	Bentonite + 15% salt	27	1.37
BT20	Bentonite + 20% salt	26	1.45
BT25	Bentonite + 25% salt	25	1.49
BT30	Bentonite + 30% salt	24.5	1.52

IV. MOISTURE CONDITION VALUE TEST

The moisture condition value test was designed by the Highways Agency of the United Kingdom. One of the important advantages of the experiment is that calculating the water content does not cause waste of time (Parsons and Boden, 1979). The test enables the determination of compaction efficiency in terms of number of blows as indicated in the standard [10]. For the experiment, 1.5 kilograms of the mixture sample, sieved through a 20 mm sieve, is taken and mixed at optimum water content as shown in Figure 3a. After that it was placed into the mold as shown in Figure 3b. A hammer with a diameter of 97 mm and a weight of 7 kg is dropped onto the sample from a vertical distance of 25 centimeters as shown in Figure 3c. After this energy is applied, due to the deformation on the soil, the hit height before the next hit is adjusted to 25 centimeters again to keep the energy constant. The hit numbers are designed to be 1, 2, 4, 8, 16, 32, 64, 128, 256. After completing each designed number of strokes, the penetration is measured with a caliper as shown in Figure 3d.

Fig. 3 MCV test stages a) Mixing b) compaction c) adjusting height d) measuring penetration

V. EXPERIMENTAL TEST PROGRAM

In this study, different amounts of salt (5, 10, 15, 20, 25 and 30%) were added to the clay. MCV tests were carried out at some multiples of the optimum water content of each mixture (0.1 intervals between 0.5 and 1.5). The standard proctor test was carried out for mixtures coded BT5, BT10, BT15, BT20, BT25 and BT30. While calculating the contribution rates, the percentage of dry soil mass was taken as basis. For example, if there is 100 grams of ground in a mixture containing 5% salt, there are 5 grams of salt. Codings were made for all mixtures. Additionally, the information on which experiment was performed on which mixture was given in detail in Table 2. Due to the large number of experiments, only the test codes of the BT5 mixture at different water contents, the explanations of these codes and the name of the experiment performed on this coded mixture are shown. Apart from this, for example, "BT10-0.8OPT" represents a mixture with a water content of 80% of the optimum value of the clay sample stabilized with 10% salt, so the final mixture is specified as BT30-1.5OPT. A total of 6 standard proctor and 66 MCV experiments were performed.

Table 2. Mixture codes and definition of the tests performed for the mixture

Mixture Code	Mixture Detail	Proctor Test	MCV Test
BT5	Clay + 5% Salt	✓	x
BT10	Clay + 10% Salt	✓	x
BT15	Clay + 15% Salt	✓	x
BT20	Clay + 20% Salt	✓	x
BT25	Clay + 25% Salt	✓	x
BT30	Clay + 30% Salt	✓	x
BT5-0.5OPT	Clay + 5% Salt mixture having water content 0.5 times of w_{opt}	x	✓
BT5-0.6OPT	Clay + 5% Salt mixture having water content 0.6 times of w_{opt}	x	✓
BT5-0.7OPT	Clay + 5% Salt mixture having water content 0.7 times of w_{opt}	x	✓
BT5-0.8OPT	Clay + 5% Salt mixture having water content 0.8 times of w_{opt}	x	✓
BT5-0.9OPT	Clay + 5% Salt mixture having water content 0.9 times of w_{opt}	x	✓
BT5-1.0OPT	Clay + 5% Salt mixture having water content 1 times of w_{opt}	x	✓
BT5-1.1OPT	Clay + 5% Salt mixture having water content 1.1 times of w_{opt}	x	✓
BT5-1.2OPT	Clay + 5% Salt mixture having water content 1.2 times of w_{opt}	x	✓
BT5-1.3OPT	Clay + 5% Salt mixture having water content 1.3 times of w_{opt}	x	✓
BT5-1.4OPT	Clay + 5% Salt mixture having water content 1.4 times of w_{opt}	x	✓
BT5-1.5OPT	Clay + 5% Salt mixture having water content 1.5 times of w_{opt}	x	✓

VI. RESULTS

In this section, calibration curves of MCV values are drawn and MCV results are presented, taking into account different salt ratios and water contents. Calibration curves were made for BT5, BT10, BT15, BT20, BT25 and BT30, respectively. MCV calibration curve of BT5 is examined in Figure 4, a sharp decrease in the MCV value is observed as the water content in increases (the value is 18.10 at $0.5w_{opt}$ and reaches 0.41 at $1.5w_{opt}$). A first-order equation emerges between the multiple of optimum water content and MCV for BT5. The mentioned equation for BT5 is $y = -14.431x + 24.083$ and the R^2 value is 0.9427.

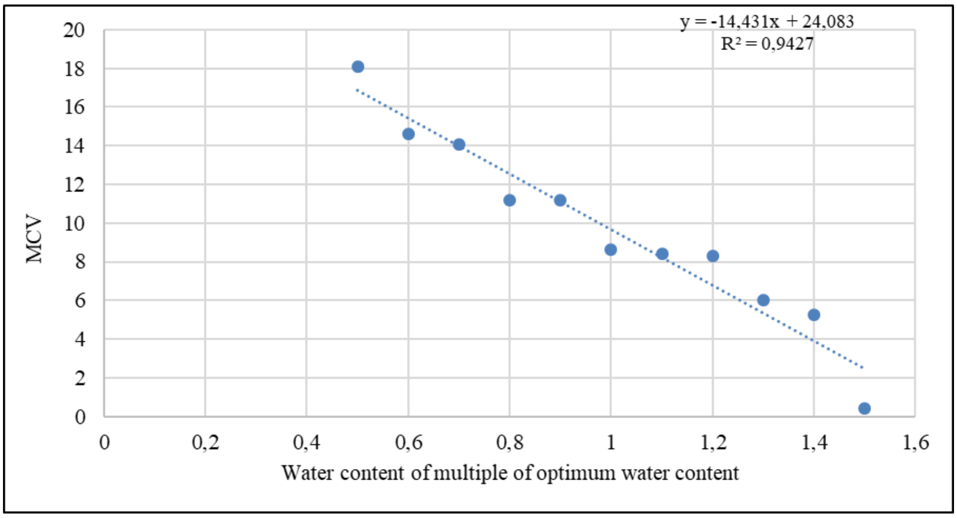

Fig. 4 MCV calibration result for BT5

MCV calibration curve of BT10 is shown in Figure 5. MCV value is dramatically decreased as the water content increases (the value is 17.60 at $0.5w_{opt}$ and reaches 3.90 at $1.5w_{opt}$). However, it is still 3.90 and better than BT5. A first-order equation emerges between the optimum water content multiple for BT10 and MCV. The equation mentioned for BT10 was found as y = - 14.691 + 25.458 and the R^2 value is 0.9567.

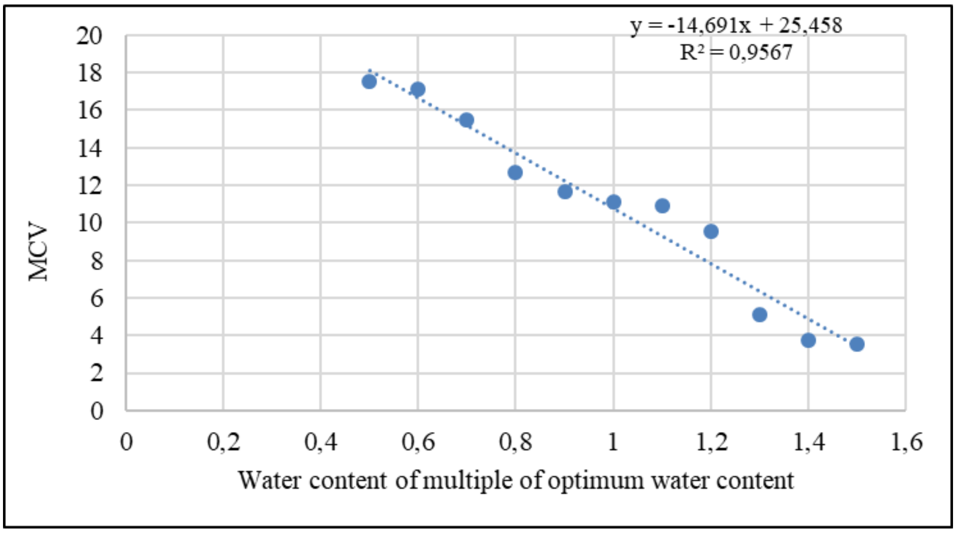

Fig. 5 MCV calibration result for BT10

When the MCV calibration curve of BT15 is examined in Figure 6, a sharp decrease in the MCV value is observed as the water content increases (the value is 17.00 at $0.5w_{opt}$ and reaches 5.90 at $1.5w_{opt}$). However, it is 5.90 and better than BT5 and BT10. A first-order equation emerges between the optimum water content multiple and MCV for BT15. The equation mentioned for BT15 was found as y = -13.891x + 25.144 and the R^2 value is 0.9606.

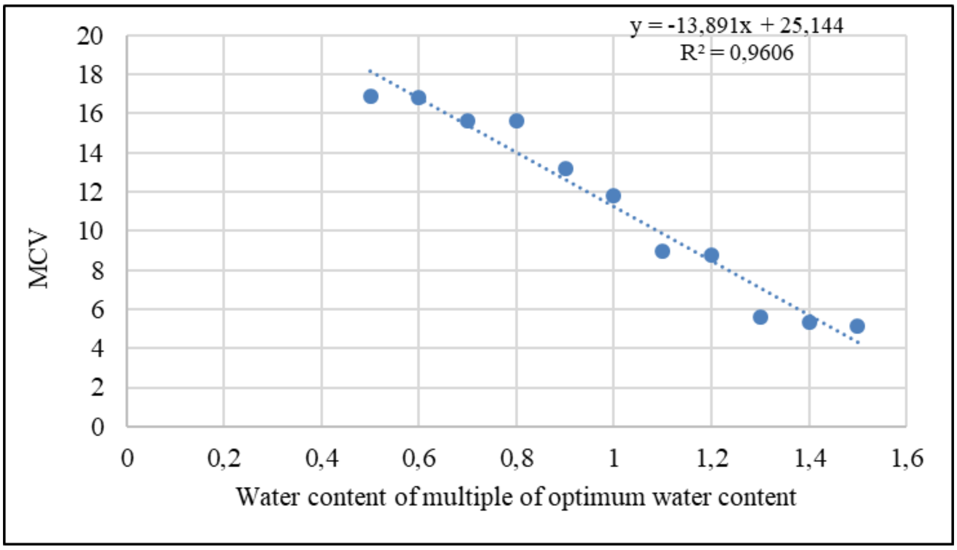

Fig. 6 MCV calibration result for BT15

MCV calibration curve of BT20 is shown in Figure 7. Decrease in the MCV value is observed as the water content increases (the value is 15.20 at $0.5w_{opt}$ and reaches 5.90 at $1.5w_{opt}$). Minimum value is as same as BT15 mixture which has a greater performance compared to BT5. A first-order equation emerges between the optimum water content multiple for BT20 and MCV. The equation mentioned for BT20 was found to be y = -10.668x + 20.323 and the R^2 value is 0.9717.

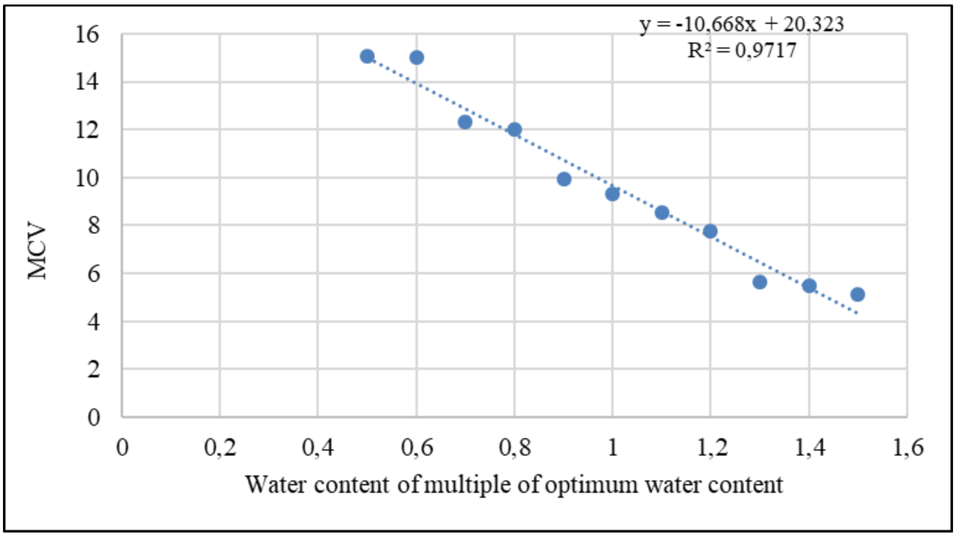

Fig. 7 MCV calibration result for BT20

MCV calibration curve of BT25 is presented in Figure 8. Increase in water content causes a decrease in the MCV value. MCV value is 15.10 for 0.5 times of optimum water while it reaches 5.70 at 1.5 times of w_{opt}. This value of MCV at $1.5w_{opt}$ is very close to BT15 and BT20. It totally proves that salt at that percentage is still good when taking into account MCV value. A first-order equation emerges between the optimum water content multiple and MCV for BT25. The equation mentioned for BT25 was found as y = - 11.408x + 20.307 and the R^2 value is 0.9608.

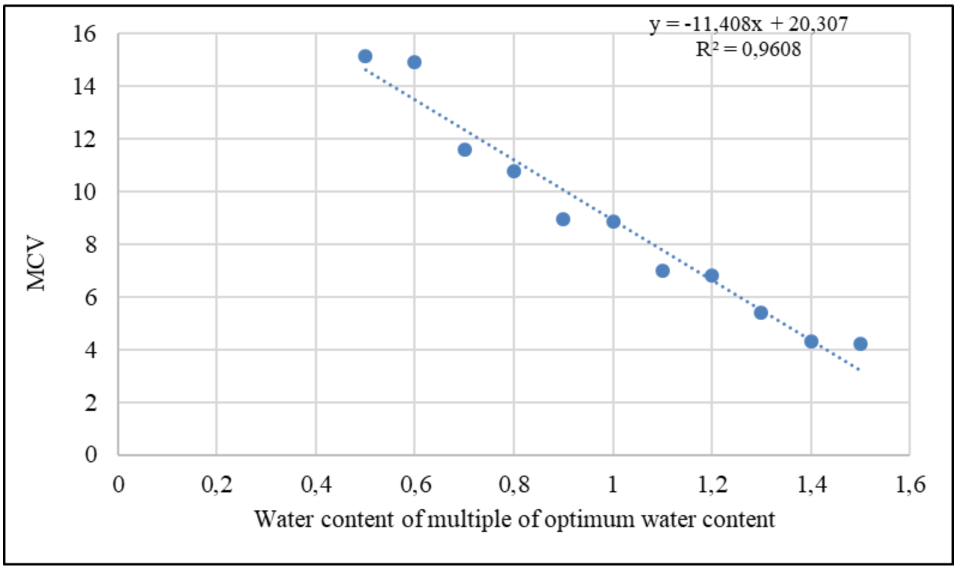

Fig. 8 MCV calibration result for BT25

MCV calibration curve of BT30 is shown in Figure 9. MCV value is observed a decrease as the water content increases (the value is 17.88 at $0.5w_{opt}$ and reaches 5.92 at $1.5w_{opt}$). BT20, BT25 and BT30 mixtures have a MCV value close to 6 at $1.5w_{opt}$. Those mixtures perform well at this water content since their MCV values (close to 6) are almost close to defined value (8.5) compared to BT5. A first-order equation emerges between the optimum water content multiple and MCV for BT30. The equation mentioned for BT30 was found to be $y = -13.591x + 23.414$ and the R^2 value is 0.9305.

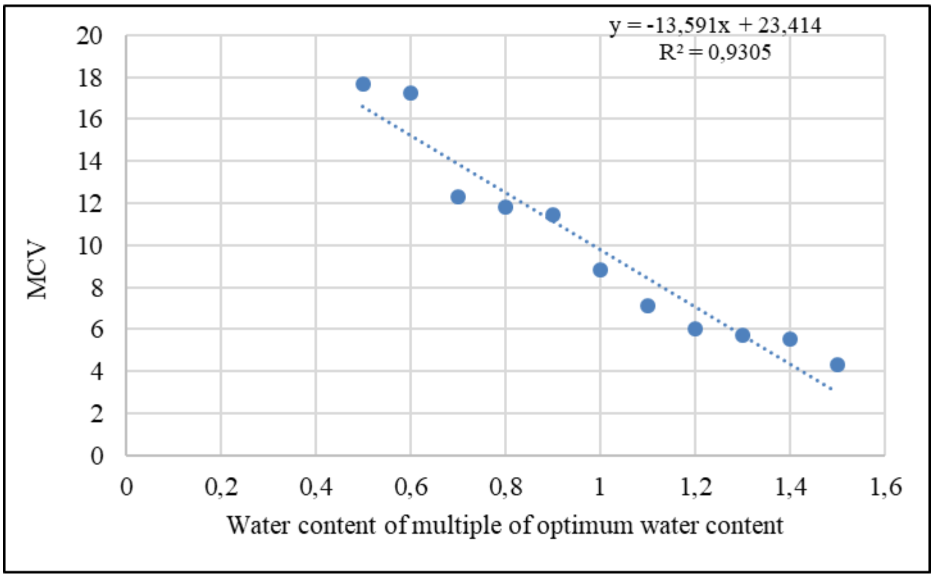

Fig. 9 MCV calibration result for BT30

VII. DISCUSSION

Significant decreases in MCV values were observed for all mixtures with increasing water content. It was revealed that there is a first degree linear relationship between MCV and water content, and R^2 values vary between 0.9315 and 0.9717. The most suitable relationship was obtained from the BT20 mixture. Mixtures having a water content higher than optimum was easy to perform and those tests were easily finished in a short time.

VIII. CONCLUSION

In this study, MCV values for soil mixed with salt with different water content (in terms of optimum solids) were examined. For each mixture group, 11 different water contents were used and a total of 66 different MCV graphs were obtained. The results stated below were obtained.

• In BT20, BT25 and BT30 mixtures, when the water content is 1.2 times or more than the optimum water content, MCV values fall below 8.5. However, in BT5, BT10 and BT15 mixtures, the values are above 8.5 at the same water content percentage. This shows that mixtures with low salt content can be more tolerant regarding water content (against water content changes due to land conditions).

• In addition, although the water content in BT15 and BT20 mixtures increased to 1.5 times the optimum value, MCV values were approximately 6. However, in BT5, the value is close to 0 at the same water content. This proves that salt added to the soil at a rate of 15% or 20% can perform well at high water contents.

• By repeating these experiments with different soil groups and/or chemical additives, different results can be obtained for soils with different plasticity and these can also be the subject of research.

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