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Effect of Drying and Wetting Cycles on the Surface Cracking and Hydro-Mechanical Behavior of Expansive Clays

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Abstract: Expansive clays present serious issues in a variety of engineering applications, including roadways, light buildings, and infrastructure, because of their notable volume changes with varying moisture content. Tough weather conditions can lead to drying and shrinking, which alters expansive clays' hydro-mechanical properties and results in cracking. The hydro-mechanical behavior of Al-Ghatt expansive clay and the impact of wetting and drying cycles on the formation of surface cracks are addressed in this investigation. For four cycles of wetting and drying and three vertical stress levels, i.e., 50 kPa, 100 kPa, and 200 kPa, were investigated. The sizes and patterns of cracks were observed and classified. A simplified classification based on main track and secondary branch tracks is introduced. The vertical strain measure at each cycle, which showed swell and shrinkage, was plotted. The hydromechanical behavior of the clay, which corresponds to three levels of overburden stress as indicated by its swell potential and hydraulic conductivity was observed. It was found that at low overburden stresses of 50 kPa, the shrinkage is high and drops with increasing the number of cycles. Al-Ghatt clay's tendency to crack is significantly reduced or eliminated by the 200 kPa overburden pressure. The results of this work can be used to calculate the depth of a foundation and the amount of partial soil replacement that is needed.

Keywords: cracks; expansive soils; swelling pressure; swell potential; hydraulic conductivity; wetting-drying cycles

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1. Introduction

Expansive soils expand on wetting and shrink on drying. This type of soil was reported to impact the economy of many urban and suburban developments worldwide. Over USD 13 billion in monetary damage is recorded annually in the United States [1–3]. Light residential or commercial buildings account for about one-third of the total damage [4]. Because of their light weight and ease of lifting and disturbance, roads, pavements, and highways indicate the highest monitory damage. Expansive clays, found in diverse locations across Saudi Arabia, pose a significant infrastructure challenge [5–9]. These clays, varying in geological origin and swelling potential, have been documented to cause damage to light structures and pavements, as evidenced in the technical literature [10,11].

The cycle of wetting and drying causes cracks to open during hot times and slowly close when water is introduced. Uneven distribution of moisture and low hydraulic conductivity of cohesive materials result in different patterns of cracks. Insufficient soil stabilization techniques can lead over time to disintegration, causing the soil surface to become more prone to cracks and movement. It is always necessary to study the swelling and shrinking behavior of expansive soil whether used alone or combined with sand to create water barriers.

Orientation, width, depth, extent, location, and the pattern of cracks can be studied alongside soil properties. Cracks can impact stability very seriously if not closely examined and addressed. Characterization is generally conducted in the laboratory [12]. Cracks can take different forms from minor hairline cracks to serious major shrinkage cracks [13]. Tension or temperature cracks can cause the soil to open and leave room for further deterioration [14]. The influence of plasticity, clay mineralogy, initial water content, and compaction characteristics have been intensively studied.

According to Al-Homoud et al. [15], irrigated soils demonstrate signs of fatigue after every wet and dry cycle, which diminishes their ability to swell. The results of Al-Homoud et al. [15] are supported by Chen's [16] research.

The repeated wetting and drying of highly plastic soils can lead to the formation of crack patterns. These patterns may vary in shape, size, and orientation. This is dependent on the type of soil, moisture content, and the exerted stresses. Intersection, an increase in width, or branching out can occur when successive cycles of drying and wetting are applied. This weakens the soil structure and causes disintegration.

A study by Osipov et al. [17] reported that durable connections in the clay structure gradually decay and transform into less durable ones as a result of repeated testing. However, they observed that expansibility increases to its maximum over longer cycles. In addition, their study is only valid after complete destruction and the emergence of a new soil structure. Under typical conditions and usage, this is not the case. Expanding soil can swell more when it experiences total shrinkage and more cycles of soaking and drying, according to Basma et al. [18].

Researchers have identified many gaps in the current knowledge of crack patterns formed in expansive soils. Long-term monitoring of crack evolution is one of the major complex challenges in addition to predicting crack propagation and the assessment of soil stability.

Case studies and field observations can provide valuable information on the behavior of expansive soil subjected to wetting and drying. A study by Chu et al. [19] claimed that as the number of cycles increases, the swelling potential first rises and then falls, suggesting that the soil structure will be destroyed by increasing drying–wetting cycles. After four cycles of wetting and drying, ref. [20] discovered that the collapse potential rises when soil is loaded over the swelling pressure. The swelling potential increases when the applied pressure is less than the swelling pressure. A study by Dao et al. [21] investigated how repeated wetting and drying cycles impact the surface cracking and volume changes in expansive soil treated with an ionic soil stabilizer (ISS). The results indicated that increasing wetting–drying cycles lead to more cracks, longer total crack length, and higher surface crack area density. They also found that the moisture content is inversely related to crack development and that absolute shrinkage increases with more wetting–drying cycles, indicating that soil shrinks further toward its center as it dries. In addition, they reported that the relative rate of expansion decreases with more wetting–drying cycles and higher overburden pressure. The relative rate of linear shrinkage initially increases and then decreases with more cycles, peaking during the second cycle. A study by Tu et al. [22] investigated the impact of wetting–drying cycles on soil strength behavior, focusing on desiccation crack development as a key factor leading to strength reduction. The study established a mechanical model to explain the decrease in soil strength due to desiccation cracks during wetting–drying cycles. Their results also show that desiccation cracks develop rapidly in the first two cycles and then slow down, with the peak deviator stress decreasing accordingly. Their main conclusion is that the development of desiccation cracks is the primary reason for the decrease in soil strength during wetting–drying cycles. Cordero et al. [23] presented the results and analysis of cracking tests carried out on samples of silty clay subjected to a drying–wetting–drying cycle to study the effect of a cyclic change in moisture on cracking behavior. The cracking pattern changes clearly with the cyclic change in moisture, showing the relationship between the soil's tensile strength and moisture. Their results provide additional new information about the effect of cyclic moisture changes on crack formation and propagation in soils. A study by Dong et al. [24] developed an instrument to simulate the wetting–drying cycles of expansive soil under actual loads, highlighting the impact of these cycles on shear strength and cohesion, emphasizing the importance of load in restricting shrinkage cracks and shear strength attenuation, and providing novel evidence for engineering design and hazard prevention in expansive soil areas. Their paper also mentions the need for further exploration of the impact of wetting–drying cycles on shear strength under actual loads. A study by Tang et al. [25] investigated the effects of wetting–drying cycles on the mechanical behavior of clay soil, focusing on desiccation-induced cracking and the role of soil suction in soil strength evolution. Desiccation cracking was observed only in the second and third stages of soil drying, with the number of crack segments increasing with wetting–drying cycles. Recent studies on cracks and the desiccation of clay include the works of [26,27], in which the authors discussed and analyzed crack evolution and crack patterns.

A commercial building in Al-Ghatt town in Saudi Arabia faced cracking and distortion shortly after completion Figure 1. Then, it was decided to abort activities because of visible cracks within the brick walls and movement in various parts in the early 1990s. The cracks started to open and close several times following seasons and patterns of rainfall and dry periods. After being abandoned for more than 30 years, the structure is still standing, and the building has started to be utilized for hosting shops and services. Its present conditions show the opening and closure of cracks. However, the risk does not seem to be serious, and the owners are likely not convinced by the potential danger and alarms pointed out by engineers and authorities. Observing cracks within non-structural members need not be taken as a serious issue, and the assessment of decisions taken for that reason needs to be revised.

Figure 1. A market building affected by expansive soil in Al-Ghatt town.

The main problem with many constructions arises after water is first added. More wetting and drying should result in fewer issues. A monitoring strategy can be applied to assess structures that experience severe discomfort. These gaps resulted in the study project being abandoned for over 20 years. It was demonstrated by the authors of this study [28] that these cracks only opened and closed within a very narrow magnitude range.

The mitigation strategies to stop this deterioration are normally carried out using stabilization methods. Lime and cement are the additives used most frequently.

The knowledge of environmental conditions is essential, and this will help to identify when expansion or shrinkage will take place. The rainfall ranges for different parts of the Kingdom of Saudi Arabia are shown in Figure 2. Figure 3 introduces details of the average rainfall in Al-Ghatt town during one year.

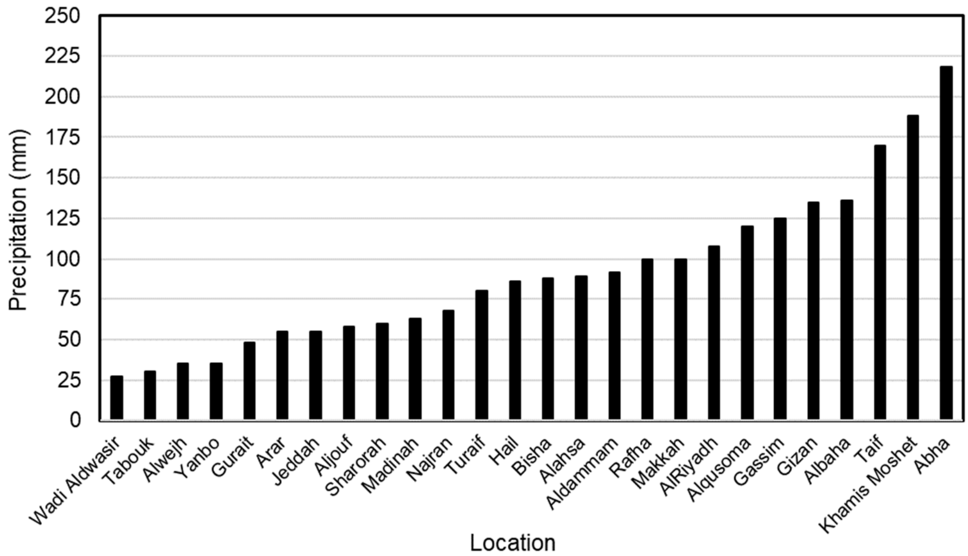


Figure 2. Annual average precipitation for selected stations in Saudi Arabia (National Center for Meteorology in Saudi Arabia).

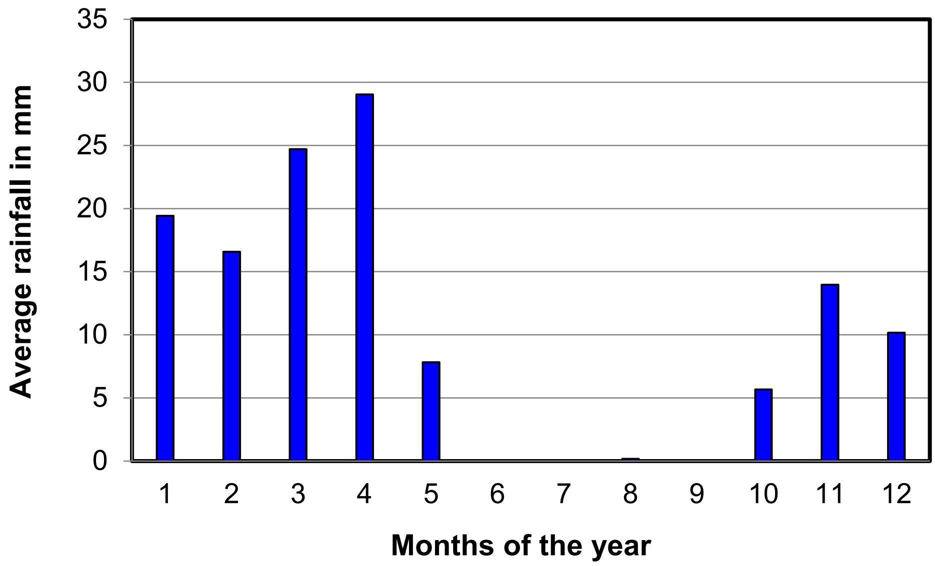


Figure 3. Average precipitation data for the Al-Ghatt region [28].

As per the National Center for Meteorology in Saudi Arabia, Figure 2 displays the average yearly precipitation measured at stations scattered across the cities of the Kingdom. Except for data obtained during the years 1985–2000 in Dammam and 1985–1990 in Wadi Aldwasir, the records span the years 1985–2019. According to recent information from the center, the unusually high average rainfall of 20.4 mm in April and May of 2023 was the highest since 1991.

The Saudi Arabian town of Al Ghatt is the subject of this research study. Four cycles of soaking and drying were applied to swelling clays supporting loads of 50, 100, and 200 kPa as contact pressures. For every stress level and wet/dry cycle, the compressibility and swelling profile were examined. Measurements were made for the primary geotechnical parameters, such as the swell potential and pressure. For every cycle at every stress level, the compressibility index and hydraulic conductivity were also calculated. Both the swelling potential and the swelling pressure were reduced by more than four times as a result of repeated cycles of soaking and drying. The cracks were classified into two types as follows: major tracks and branching tracks. Measurements of cracks at the end of each drying cycle were conducted, and the effect of these cracks on the hydraulic conductivity and other swell parameters was discussed. The vertical field displacement for two buildings in Al Ghatt town was observed over a six-month period compared to a point not supporting a building. This was conducted to show the seasonal effect on clays supporting heavy and light loads.

This study addresses the drying and wetting cycles of plastic clays and the associated cracks when adverse environmental conditions prevail. A simplified classification of cracks is presented along with the hydromechanical behavior of expansive soils under practical stresses of 50, 100, and 200 kPa.

2. Materials and Methods

2.1. Materials

The materials used for the investigation in this study were obtained in Al-Ghatt town in the central region of Saudi Arabia. Al-Ghatt town is the first urban area in the Kingdom recognized for the hazard of expansive soils. The area became the subject of numerous studies related to expansive soils. The formation in this region is dominantly clayey shale of low to medium plasticity with minerals including smectite, vermiculite, chlorite, Illite, and mica [28]. Many parts of the town experienced serious cracking and damage to light structures. The general physical properties of this soil are presented in Table 1.

Table 1. Physical properties of Al-Ghatt soil.

Value	Property
40 to 70	Liquid limit (%)
15 to 35	Plastic limit (%)
20 to 40	Plasticity index (%)
15	Shrinkage limit (%)
13	Linear shrinkage (%)
87 to 90	% Finer than 200 µm
2.7 to 2.8	Specific gravity
3.2 to 10	Natural moisture content (%)
16.4	Maximum dry density (kN/m^3)
25	Optimum moisture content (%)
40 to 1000	Swelling Pressure kN/m^2
0.01 to 0.20	Swell index

2.2. Testing Procedure

2.2.1. Sample Preparation

The field-obtained Al-Ghatt clay was air-dried, ground, and sieved using sieve No. 40. According to ASTM D698 [29] was followed to determine the maximum proctor density value and the optimum moisture content. After adding and mixing the target moisture content, the mixture was kept in plastic bags for at least 24 hours. In a stainless steel consolidometer ring with a diameter of 63.5 mm and a height of 20 mm, samples were produced by static compaction to the desired unit weights. The final sample height of 16 mm included a 4 mm recess to accommodate sample expansion.

2.2.2. Procedure of Wetting and Drying

A conventional oedometer cell was used to investigate the wetting and drying of Al-Ghatt clay. In order to test the specimens, two porous stones were positioned in 63.5 mm consolidation rings, with a load plate resting on the upper stone. The test procedure included wet loading, which was started by applying a seating load of 7 kPa to the specimens during the free swell stage. The vertical strain (swell) was continuously monitored. When the specimen height changed at a negligible pace, equilibrium swell was presumed.

The specimens were loaded progressively up to a target stress after reaching equilibrium. A drying stage was initiated by halting measurement for all devices and then emptying water from the cell once the specified compression stress (chosen stresses of 50, 100, and 200 kPa) was reached. The specimens were then weighed and measured before being put into an oven that was kept at a steady 50 °C. To prevent future weight changes, the specimens for each stress level were allowed to completely shrink. A single wet–dry cycle was defined as the completion of one swelling under a selected load followed by a subsequent shrinking.

A collection of samples was exposed to stresses of 50, 100, and 200 kPa, which are expected to occur under a specific structure, in order to examine wetting and drying in a manner that is comparable to what occurs in the field.

In the laboratory, the drying process was carried out at 50 °C, which is the maximum summertime temperature that is likely to occur in Al Ghatt. Every stress level that was chosen had four drying cycles applied to it. Compressibility parameters, hydraulic conductivity, and swelling potential were all measured and reported.

2.2.3. Procedure for Swelling and Compressibility Tests

One-dimensional consolidation tests were used to evaluate the samples' swelling behavior. All samples were initially prepared with the highest possible dry unit weight and optimal moisture content. To reduce side friction, remolded samples were compacted inside a stainless steel ring measuring 63.5 mm in diameter and 20 mm in height. Each sample was placed above a 4 mm recess to allow for future growth. In order to assess heave, each test cycle consisted of a dry loading stage with a seated load of 7 kPa and a free swell stage where the sample was submerged under the same stress. The target stress (50, 100, or 200 kPa) was reached when the stress was raised to 25 kPa, and at each point, the equilibrium was verified by the cessation of deformation. After every cycle, the sample was taken out of the testing cell so that the procedure could be prepared and repeated in the next cycle.

2.2.4. Hydraulic Conductivity Tests

One-dimensional consolidation tests were used to estimate hydraulic conductivity in the samples indirectly based on Terzaghi's consolidation theory (1948). This method is predicated on the idea that the amount of hydraulic conductivity and the water flow rate during loading are related. The following equation can be used to determine hydraulic conductivity at any load:

$$k = c_v \cdot m_v \cdot \gamma_w \quad (1)$$

where:

c_v is the coefficient of consolidation.

m_v is the volume of compressibility of the soil $[(\Delta e/\Delta P)/(1 + e_{av})]$; Δe is the change in the void ratio due to the load increment; ΔP is the change in stress; and e_{av} is the average of the void ratio at load.

γ_w is the unit weight of water.

The testing involved compacted samples confined within a stainless steel ring and subjected to target stresses of 50, 100, and 200 kPa. Throughout the primary consolidation phase, vertical deformation was continuously monitored using an LVDT to determine the void ratio after the loading stage.

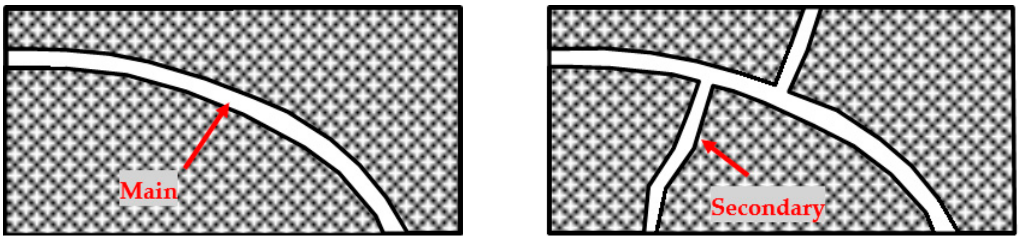
2.3. Field Monitoring

Monitoring cracks resulting from expansive soil movement is a useful tool for assessing the level of damage and disintegration of subsurface soil. A previous study on the cracks of a building was surveyed by the authors and introduced by [28]. By tracking motion joints in the same building in Al-Ghatt, the authors showed that when it gets dry, from May to September, the distance across the joints closes. By October, when it usually rains, the distance stops closing. Rainfall does not occur in November; it resumes in January. Until January, when expansion commences, the building reaction is essentially consistent.

The peak of expansion lasts until April, after which the soil begins to contract again until September. Instead of measuring crack width, in this study, we observed the vertical movement of two buildings founded on two different types of foundations, namely, a rigid invert T section strip and conventional isolated pad foundations. The movement was compared to a point in the street supporting no structure.

3. Introducing A Simplified Crack Classification

Classifying cracks can be a useful tool to predict moisture movement. The approach of crack patterns is derived from four cycles of wetting and drying. Digital image processing is based on a new concept of main tracks and branching tracks. A main track is created by shrinkage and tension failure of a clay lump. The direction and orientation depend on the clay fabric's uniformity. Non-uniform paste influences the direction of the main and branching tracks. A branching crack occurs when a weaker zone adjacent to the main track boundary starts to split. The orientation is based on the tension capacity of clay caused by a temperature increase. In this study, cracks in expansive clay were divided into two main types as follows: a main track and a branching track (Figure 4). These two main features are the primary cracks considered in recognition and assessment. Secondary branching and tertiary branching take place following the same concept but are not included in parameter measurements. The AutoCAD 2024 computer program was used to measure the cracks that formed at the end of drying cycles using photographs of the soil samples, and the drawings enabled calculations of the crack widths and lengths.



(**a**) Main track crack (**b**) Secondary branch track cracks

Figure 4. Types of cracks proposed in this study: (**a**) main track cracks and (**b**) secondary branch track cracks.

This study was limited to two types of cracks that influence the behavior of clay. The hydraulic conductivity measured for the clay is considered not valid, and the main track geometry governs the flow. The secondary branch tracks developed further in tertiary and higher-order degrees are not likely to influence closing at a short distance.

4. Results and Discussion

The effect of drying and wetting cycles on the surface cracks and hydro-mechanical behavior of expansive clay has been a topic of intense research in geotechnical engineering. This phenomenon is of significant importance as it directly impacts the stability and performance of structures built on expansive clay soil. Understanding the behavior of expansive clays under drying and wetting cycles is crucial for designing effective foundation systems and mitigating the potential risks associated with these types of soils.

The swelling potential, as shown in Figure 5, is reduced by more than four times as a result of repeated cycles of wetting and drying. The vertical strain vs. time for 50, 100, and 200 kPa exerted pressures are shown in Figures 6–8.

The vertical strain is reduced at the fourth cycle for stresses of 100 and 200 kPa. While a reduction is also observed for the stress of 50 kPa, the total strain value still remains high. This is due to the light weight applied. The second cycle shows an unexpected drop in vertical movement. The soil fabric was usually damaged after multiple drying and wetting cycles.

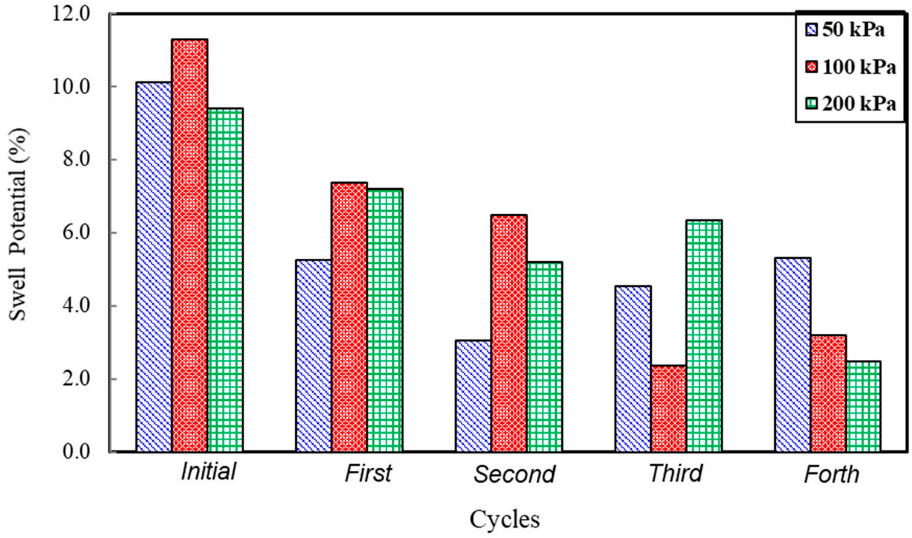


Figure 5. Swell potential vs. wetting and drying cycles.

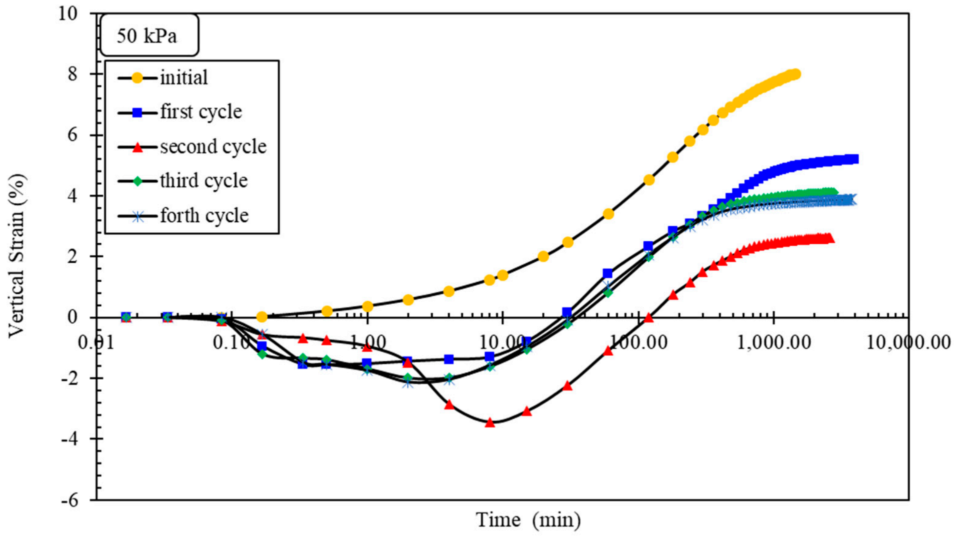


Figure 6. Vertical strain vs. time for 50 kPa samples.

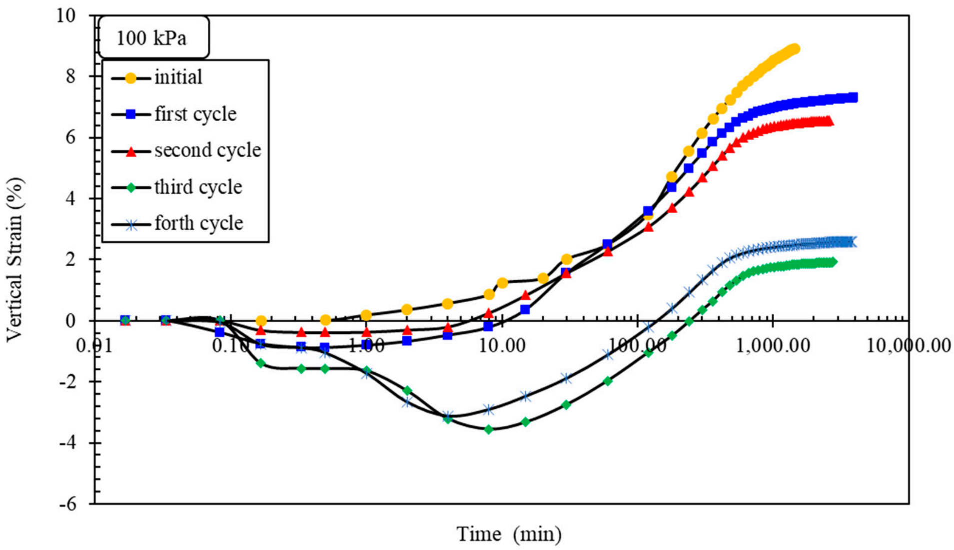


Figure 7. Vertical strain vs. time for 100 kPa samples.

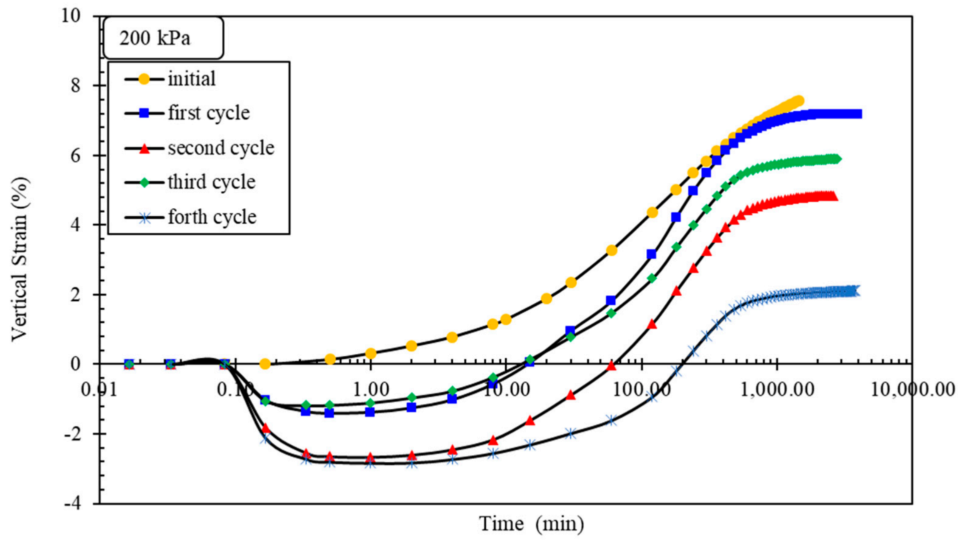


Figure 8. Vertical strain vs. time for 200 kPa samples.

This reduction can be explained by the disturbance of the clay mass, in which density and soil fabric are affected. The vertical movement is closely related to the horizontal movement as both are induced by shrinkage. This study is very relevant to the evaluation of cracks and lateral disintegration.

On the other hand, the hydraulic conductivity is noted to decrease with the increase in applied pressure for all cycles. In addition, the hydraulic conductivity decreases with the number of wetting and drying cycles until the second cycle, after which the trend is reversed (Figure 9).

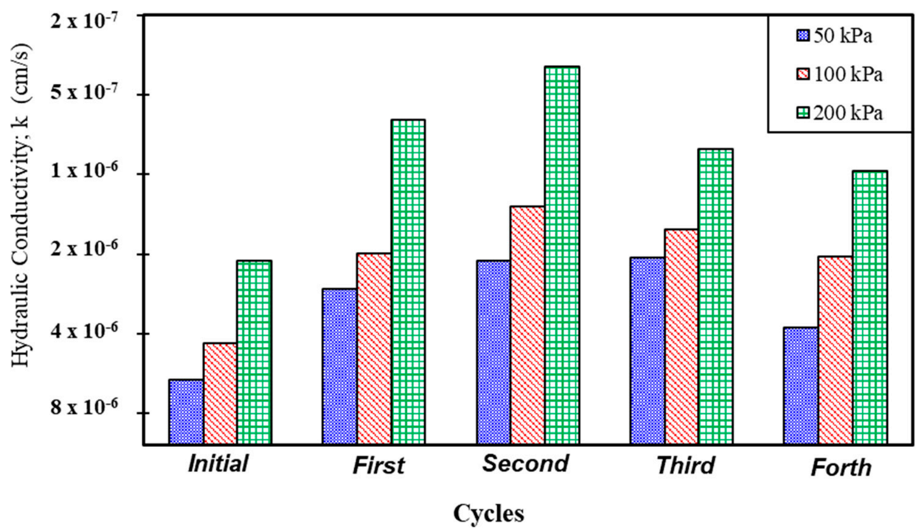


Figure 9. Hydraulic conductivity vs. cycles.

The risk of cracking is largely reduced at 5 m below grade and becomes negligible at 10 m below grade. This result will help in assessing decisions of partial or full soil replacement.

This result justifies the success of the founding system used in the Al-Ghatt court building, where a partial soil replacement of 1.5 m was considered along with an inverted T section. Although the inverted rigid system played a significant role, soil replacement was added as an extra protection method.

The cracking trends were carefully studied for four different drying and wetting cycles under surcharge stresses of 50, 100, and 200 kPa. This study used a simplified definition of cracks regarding size and initiation. The major track cracks are first formed because the clay planes fail under tension. The direction of the crack is dictated by the weak parts that fail to withstand shrinkage tension. The width of the crack is a function of the tension caused by drying, the plasticity of the clay, and the homogeneous nature of the paste. Secondary track cracks start to develop when major cracks reach their maximum width. These secondary tracks are smaller in size compared with the major cracks. The shrinkage caused by the temperature gradient acts on a smaller size or part of the clay. Tertiary and higher-order cracks can also form but will always be smaller in size than secondary track cracks. Figure 10 demonstrates the stages of forming major tracks and secondary tracks for the three overburden pressures.

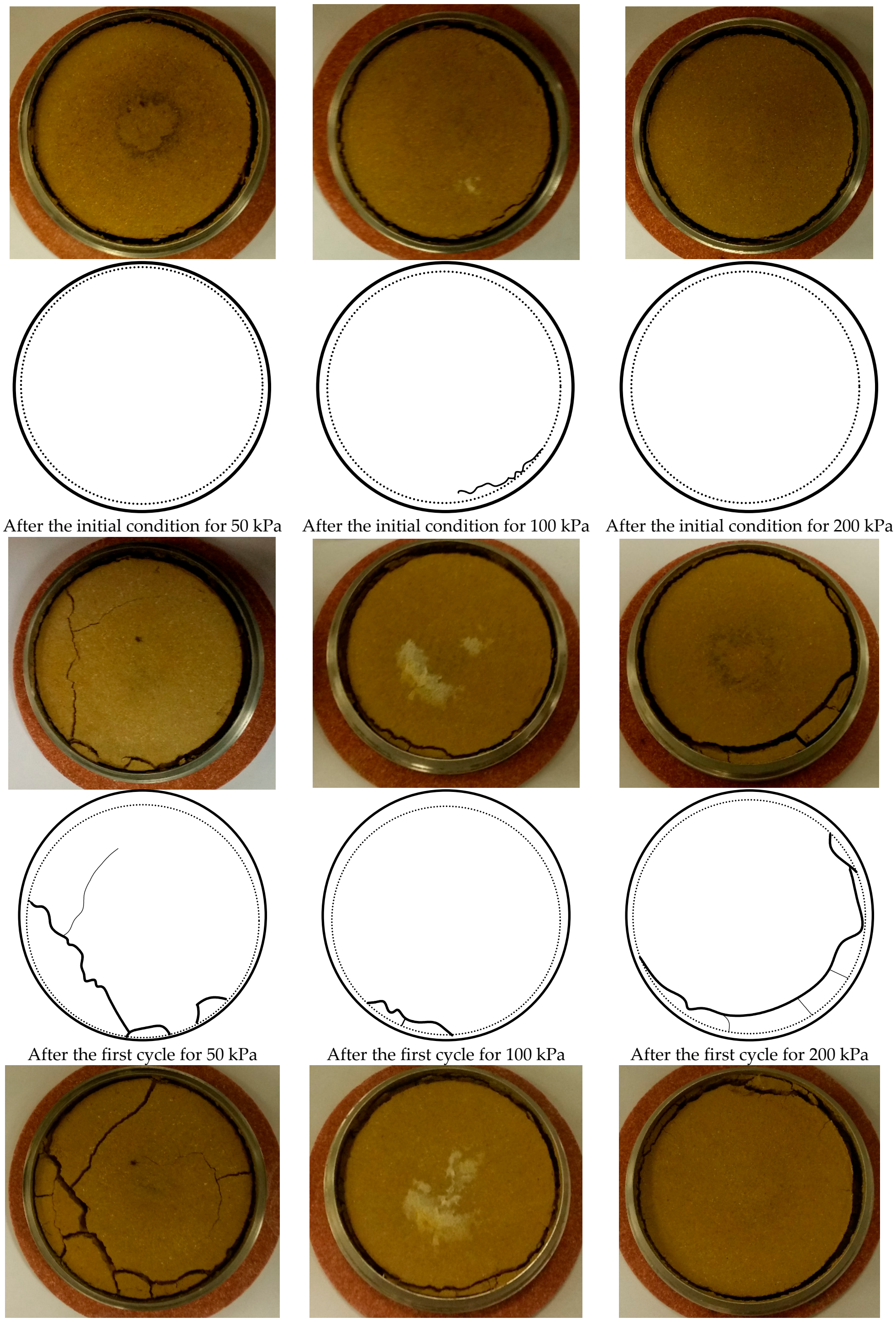


Figure 10. *Cont*.

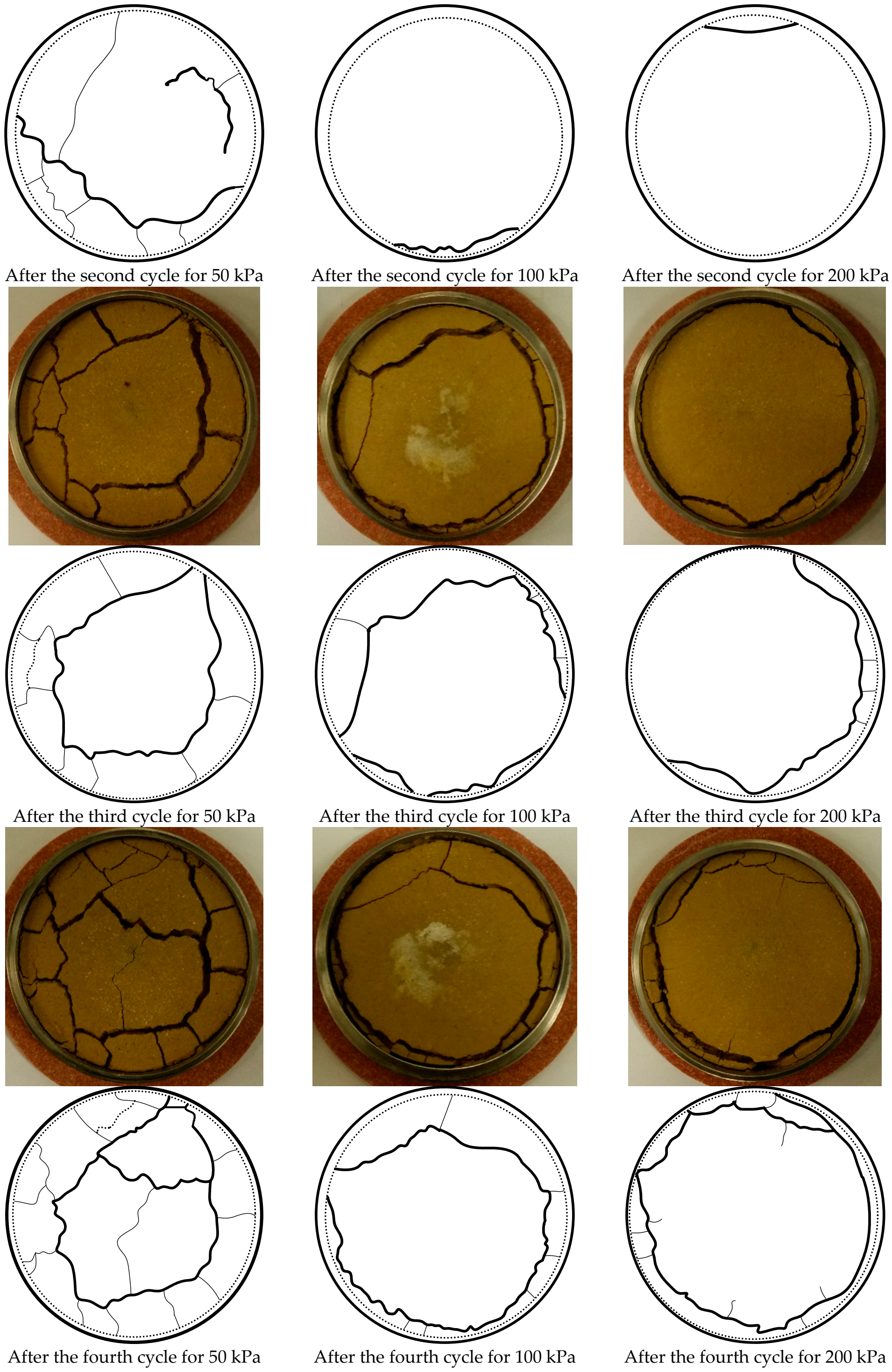


Figure 10. Main and secondary branching track maps before and after four wetting and drying cycles.

A study by Al-Zubaydi [30] explored the effects of wetting and drying cycles on the swell/collapse behavior and cracks in fine-grained soils and the factors influencing the behaviors of soils from Al-Mosul city. His work confirmed the general trend observed in this study and found that collapse potential is influenced by soil type and applied loads. Also, Li et al. [31] explored the impact of wetting–drying cycles on the crack development and strength properties of expansive soil, establishing a linear relationship between crack ratio and strength to help predict soil strength. They found that changes can reach a limit value with ongoing wetting–drying cycles, similar to what was observed in the fourth cycle.

The measurements for the three target stresses are tabulated and presented in Table 2. The initial stage prior to the first cycle is listed along with all four cycles. The average width of the main crack increases with the number of cycles.

Table 2. Measurement values of cracks during drying cycles for all loading series.

Target load = 50 kPa	**Initial**	**First Cycle**	**Second Cycle**	**Third Cycle**	**Fourth Cycle**
Average width of the main track (mm)	0	0.7	1.4	1.5	1.7
Average width of branch secondary track (mm)	0	0.3	0.8	1.2	1.35
No. of cracks	0	2	7	9	14
% of total shrinkage/total volume	13.9	7.7	8.6	3.1	9.8
% volume of crack voids/total volume (main)	0	0.91	3.15	6.31	7.0
% volume of crack voids/total volume (secondary)	0	0.21	3.17	2.1	2.2
Presence of tertiary cracks	N	N	N	Yes	Yes
Target load = 100 kPa					
Average width of the main track (mm)	0	0.5	0.9	1.9	2
Average width of branch secondary track (mm)	0	0	0	1	1.1
No. of cracks	0	1	1	4	5
% of total shrinkage/total volume	16.5	16.5	11	5.5	11
% volume of crack voids/total volume (main)	0	0.38	1.1	6.3	5.5
% volume of crack voids/total volume (secondary)	0	0	0	0.43	0.25
Presence of tertiary cracks	N	N	N	N	N
Target load = 200 kPa					
Average width of the main track (mm)	0	2	1.3	2	2.1
Average width of branch secondary track (mm)	0	0.8	0	0	0.4
No. of cracks	0	4	1	1	7
% of total shrinkage/total volume	16.5	11.3	12.8	6.5	1.5
% volume of crack voids/total volume (main)	0	3.2	0.8	5	7.7
% volume of crack voids/total volume (secondary)	0	0.104	0	0	0.15
Presence of tertiary cracks	N	N	N	N	N

The crack measurements for the four cycles indicate that the main track crack size varies from 0.5 mm to 2.1 mm. Secondary track cracks are smaller in size but do not necessarily follow an increasing order. They are not even present at some stages. The total shrinkage compared with the total volume decreases with the increase in drying and wetting cycles. It is worth noting that at low overburden stresses of 50 to 100 kPa, the total shrinkage increases after the third cycle. The trends in secondary track cracks are random and cannot be related to the increase in external influence. It can be concluded that the percentage of shrinkage drops with an increasing number of cycles. The main track size can be related to the number of drying and wetting cycles. Secondary track cracks are random and occur excessively at low overburden stresses.

Six-month observations were carried out for the vertical movement of Al-Ghatt expansive clay as shown in Figure 11. For the case where no structure is supported by the clay, expansion was reported in four months and compression was reported in two months (Figure 12). The expansion is due to the rainy seasons or wetting of the ground for irrigation purposes. The rigid foundation system did not indicate any expansion throughout the observation period except for minor movement in June.

A nearby building found on isolated pads settled at 2 mm in four months and 0.1 mm and 0.75 mm in the months of April and June (Figure 13).

It is rather difficult to judge the vertical and downward movement without the influence of shrinkage and wetting effects. This field study aimed to verify the changes in vertical movements due to environmental exposure.

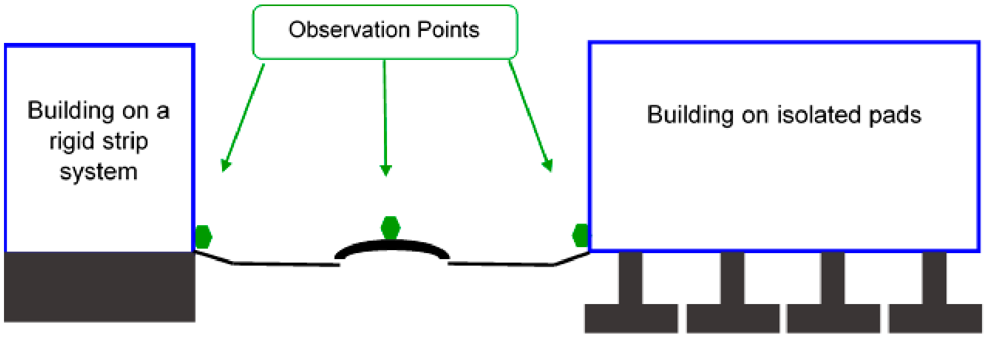


Figure 11. General sketch of field observation points at Al-Ghatt.

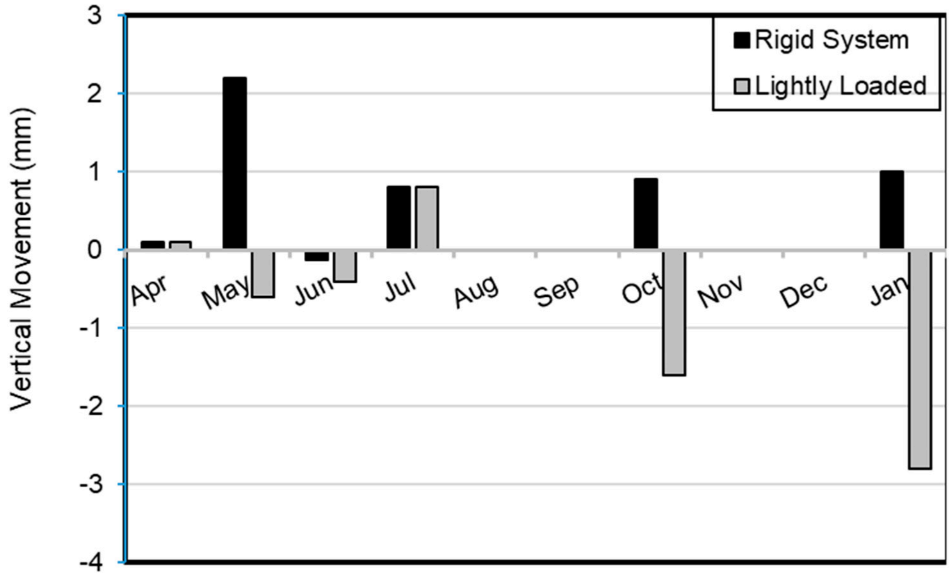


Figure 12. Results of vertical movement measurements comparing a rigid system with a lightly loaded point.

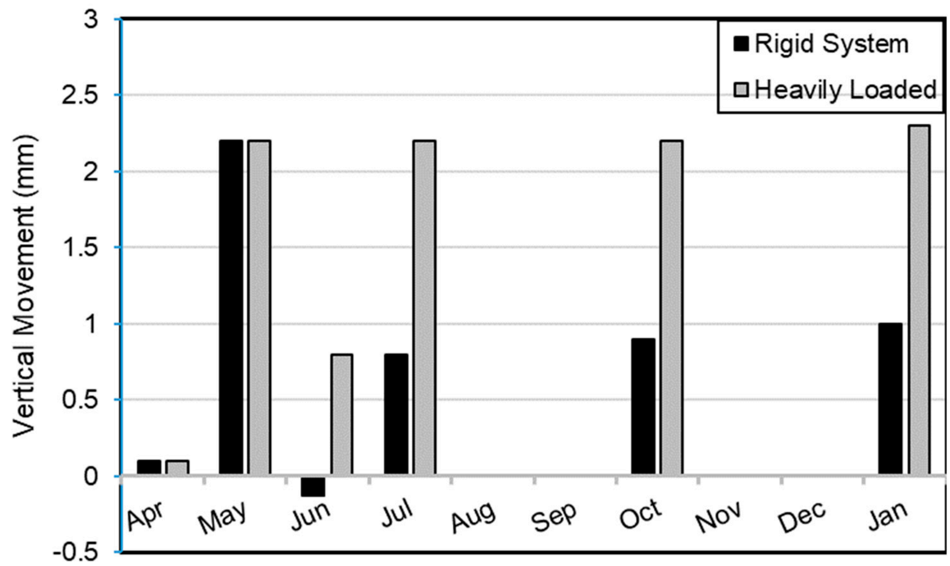


Figure 13. Results of vertical movement measurements comparing a rigid system with a heavily loaded point.

Dao et al. [21] present experimental results on the impact of wetting–drying cycles on surface cracking and the swell–shrink behavior of modified expansive soils using parameters like height, the relative rate of expansion, and linear shrinkage [23,32,33]. They addressed this by conducting a unique experiment using an environmental chamber and a cylindrical silty clay specimen. By controlling the relative humidity within the chamber and monitoring key variables like temperature, suction, and water content, they investigated crack evolution during a cycle of desiccation, wetting, and subsequent desiccation. Their research revealed a significant alteration of the crack pattern under varying humidity conditions, with a notable increase in cracking observed upon wetting the soil after a dry period.

5. Conclusions

This study presented the cracking patterns associated with the vertical strain of Al-Ghatt clay at three overburden pressures. Three vertical stress levels of 50 kPa, 100 kPa, and 200 kPa were investigated for four cycles of wetting and drying. The patterns and extent of cracks were monitored. This study suggested a simplified classification of cracks based on their development and progress. The main conclusions are as follows:

- This study introduced and defined major track cracks and secondary branching tracks as a reference to investigate cracking in clays.
- The hydro-mechanical behavior was presented, as indicated by the hydraulic conductivity and swell potential of the clay, corresponding to three overburden stress levels. The hydraulic conductivity is measured in the range of 5.7×10^{-6} to 3.7×10^{-7} cm/s.
- The swelling potential was found to reduce by more than four times as a result of repeated cycles of wetting and drying. The hydraulic conductivity was noted to decrease with the increase in overburden pressure and also the number of wetting and drying cycles except for the fourth cycle, where the trend was reversed. The major track cracks were first formed when the clay planes failed under tension. The width of the crack was a function of the tension caused by drying, the plasticity of the clay, and the homogeneous nature of the paste. Secondary track cracks started to develop when the major cracks reached their maximum width. These secondary tracks were smaller in size compared with the major cracks.
- The effect of the overburden pressure was found crucial to reduce or eliminate the cracking nature of highly plastic clay. The outcome of this work can be used to determine the level of partial soil replacement required and foundation depth.

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